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The Dynamics of Urban Systems: The U.S. Experience and further Steps Towards Modeling Change

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by P.M. Allen, M. Sanglier,
G. Engelen and F. Boon.

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The Dynamics of Urban Systems: The U.S. Experience and Further Steps Towards Modeling Change

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INTRODUCTION

The work presented in this report is the further extension of research performed under previous contracts with the Department of Transportation (TSC-1185-1460-1640). In this further work there are two basic aims being pursued simultaneously. Firstly to attempt some practical study of the evolution of urban systems in the United States using the new theoretical ideas that were developed in our earlier work. Secondly, to further extend and deepen our models and their theoretical foundations as well as clarifying and rendering explicit the mutual interaction and evolution of a transportation network and its corresponding urban structure.

In part I, concerning the application of our methods to a study of the evolution of urban structure within the United States we begin with a description and analysis of changes that have occurred over the past three decades or so. What emerges is that locational criteria for economic activities as well as for residential population have changed, possibly as a result of greater wealth, from being dominated by strictly economic evaluations, to include psychological and social considerations.

Such a change of behaviour is in agreement with the discussion given in a previous report which underlined the fact that decisions are always framed in a multi-dimensional value space, where personal satisfaction and prestige play a role along with economic criteria. The relaxing of economic constraints would lead naturally to a transfer of weight to the other dimensions. The new behaviour is no less "rational", whatever that means, but the rationality has changed and it is certainly less easily stated in dollar values.

The emergence of this wider set of considerations apparently more subjective and related to the perception of space of an actor suggests strongly that the modelling of urban processes should include the "mental maps" of the interacting actors. The importance of these new psychosocial location criteria, coupled with the evolution of technology have fundamentally reorganized the spatial structure, producing new spatial inbalances with high social and economic costs.

The changes within cities reflect the increasing centralization of administrative, professional and financial employment and the decentralization of jobs in manufacturing and distribution, together with the outward spread of white collar suburbs and the development of large, planned sub-

urban shopping centers. Such evolutionary trends, coupled with increasing commuting costs and high mortgage interest rates inject strong tensions into a seemingly smooth process of change.

On the scale of the nation as a whole the pattern of growth has changed from the basic heartland/hinterland interaction to a new one, where the changing sectorial mix of the economy, and simply the maturity of the system have led to the breakdown of the economic domination of the North-East. A new pattern is emerging dominated by the growth of large regional metropolitan areas each of which both saps and vitalizes the area around it. Instead of a single heartland/hinterland, we have moved to a situation of several interacting heartland/hinterlands.

This analysis has led us to the recognition of 3-levels of spatial disaggregation for the modelling of the spatial dynamics within the United States : the national level; the regional level; the intra-urban level. Here we identify these levels, and discuss the choice of the North East Central Region and the City of Detroit in our future modelling effort.

The second part of the report is concerned with extending the theoretical basis or our model. Our previous

intra-urban model has been revised to encompass the behaviour of seven basic types of urban actor, where employment in the local industrial sector has been added to the six of our preceeding equations : Exporting Industry, Finance and Business, Blue collar and White collar workers, and frequent and rare consumer goods and services.

The model is described in some detail, and the values assigned to the various parameters is discussed, and this is followed by a study of the different phases of growth revealed by our model, as well as an exploration of the effects of varying the different parameters on the emerging urban structures and traffic flows.

In Chapter 4 of this second part, we introduce explicitly a transportation network where each link of each mode is characterised by a time and money cost. A program has been developed which calculates the costs (time and money) between any two points, and thus allows us to calculate the access of residential locations for blue and white collar workers, taking into account their different sensitivities to time and money costs.

The inclusion of a complex transportation network into our dynamic models is a major step forward allowing us to ,alculate usership of each link, automobile traffic flow,

etc..all as part of an evolving urban structure. Also, despite the apparent 'hexagonal' structure or our figures, we should underline that by specifying the network we are in fact no longer restricted to representing any regular shapes. Any real city can now be described, as can the mutual development of urban structure/traffic flows/transportation networks.

In the final section we have begun work on the development of a classification of urban structures. This will allow us in the future to indentify those characteristics, economic, ethnic, social and spatial which are decisive in the description of its behaviour and evolution, in particular with respect to the provision or suppression of public transportation, different pricing policies, etc....

Our new perspective of the dynamics of urban structure shows us that the precise prediction of the future evolution of a city or system of cities is impossible. What may be explored however, is the stability of different possible paths of evolution, and the 'danger' that one or another new type of structure may emerge. Thus, it seems important to define different types of cities, and to explore the possible futures of these types under different scenarios.

This research is now under way.

PART ONE :

FIRST STEPS OF AN APPLICATION OF URBAN AND REGIONAL MODELS TO THE CASE OF THE UNITED STATES.

X

CHAPTER 1 - THE RECENT FUNDAMENTAL TRANSFORMATION OF THE URBAN STRUCTURE IN THE UNITED STATES.

I. - THE CHANGING OCCUPATIONAL STRUCTURE OF THE METROPOLIS

The United States is a highly dynamic system, undergoing rapid and strongly nonlinear transformations. There are different levels of change in the spatial structures.

The first level of increasing disequilibrium is that of the relationship between central-city and suburbs.

As Berry and Kasarda state it (1) :

"The centrifugal and centripetal forces of urban expansion "operate on two fundamental sectors and the metropolitan "community - the residential sector and the employment sec- "tor -..... Our central cities are becoming the domain of "disproportionately large numbers of less educated, blue- "collar workers while the suburban rings are developing as "the residential locus of the better educated, white-collar "worker. Unfortunately, conflicting movements have been oc- "curing in the employment sector... Jobs having lower edu- "cation requirements, such as those in manufacturing and "standard consumer trade, are dispersing to the suburban "rings; meanwhile, jobs requiring higher education, such as

"those in administration, the professions, and specialized "business services, are accumulating in the central cities. "These conflicting movements have tremendously increased "the daily commuting movements from the suburbs to the cen- "ter and from the center to the suburbs.

"The changing distribution of employment opportunities "in the metropolis has been especially detrimental to large "numbers of lower-class residents of the central cities, "particularly poor minority groups. The educational back- "grounds of these people are not appropriate for the new "functions accumulating in central cities, and many cannot "afford the growing cost of commuting by automobile to blue- "collar jobs dispersed throughout the suburban rings. More- "over, suburban zoning restrictions on low-cost housing and "discriminatory practices prevent the vast majority of the "urban mass from obtaining inexpensive residential sites "near expanding suburban industries. The outcome is that "central-city unemployment is now more than twice the natio- "nal average.....

"High unemployment rates and concomitant rising welfare "rolls among central-city residents are only two of the de- "leterious implications of the changing structures of the "metropolitan areas. The centrifugal and centripetal move-

"ments of expansion also have been instrumental in eroding "the tax base of central cities, while creating an even "greater need for public services in the city. Most of our "central cities are plagued with rising debt service, with "no apparent reversal of the trend in sight.

Why do specific types of employment and residents decentralize? "The initial development of road transport and "highway improvement did indeed breed a continuous and gra- "dual decentralization of people and jobs in the core-orien- "ted metropolis through the first half of the twentieth cen- "tury. But then came a series of technological changes in "rates of decentralization.

"On the manufacturing side, superhighways, large-scale "trucks, and piggyback combination road and rail transport "reversed the pull of rail terminals and docks in central "areas on industrial location .... Peripherical location "became as (or even more) accessible to the metropolitan re- "gion than was the traditional city center. With the remo- "val of traditional constraints, the negative externalities "of the central city loomed large in choice, both percep- "tually and in fact. The locational choices of the subse- "quent massive decentralization of industry were dictated "more by social factors and prestige locations than by tra-

"ditional dollars and cents - low status locations - poor, "polluted, and black neighborhood - were left and avoided by "new concerns.

"For retailing, the significant development was the in- "vention of the planned shopping center, a dramatic and "drastic technological change. In the early years, develo- "pers followed the growing suburban market with a hierarchy "of neighbourhood, community and regional centers. The "first centers were oriented to the more affluent sectors of "the biggest cities and diffused from them to smaller places "and lower-income suburbs. In the 1960's, a fundamental "change in shopping-center developers' concepts became appa- "rent. Again the suggestion of the social dynamic is there, "replacing much of the economic dynamic of conventional wis- "dom. This social dynamic involves not only the avoidance "of the central city by the majority of white residents, but "also the creative, style-setting leadership envisaged by "major shopping center developers who are busy building on "the metropolitan periphery ahead of residential growth. By "leading rather than following, the new developers seek to "establish the direction of metropolitan growth, set the "style and tone for the suburbs to follow, and capitalize on "the new opportunities thereby created ... New communica- "tion media have contributed to cognitive changes by provi-

"ding the universal perception of decaying central cities of "old neighbourhood now the domicile of low-income minorities "the immediate on-the-spot coverage of violent crime; the "careful documentation of the frustations of city life; and "acute awareness of emerging separatist feelings. It is no "accident that the suburbanization of white city-dwellers "has increased, supported by rising real incomes and increa- "sed leisure time. Similarly decentralizing commerce and "industry avoids the low status central city location, and "the new office complex seals itself in by defensive techni- "ques.

The second level of increasing spatial disequilibrium can be located at the regional scale, not as considered traditionally, in the relationships between heartland and hinterland, but in the relationships between metropolitan areas and inter-metropolitan periphery. In order to grasp better these mechanisms let us describe first the basic evolutionary trends of the economy at the national level.

II. THE CHANGING NATURE OF REGIONAL GROWTH.

Throughout the first half of the twentieth century, the spatial dynamics of the United States has been generated on the basis of two main components.

On the one hand, "the central driving force has been a "great heartland nucleation of industry and the national "market, the focus of the large scale national serving in- "dustry, the seedbed of new industry responding to the dyna- "mic structure of national final demand, and the center of "high levels of per capita income(2).

On the other hand, "standing in a dependent relationship to "the heartland, radiating out across the national landscape "are.... resource dominant regional hinterlands specializing "in the production of resources and intermediate outputs for "which the heartland reaches out to satisfy the input requi- "rements of its great manufacturing plants. Here in the "hinterlands, ressource-endowment is a critical determinant "of the particular cumulative advantage of the region and "hence its growth potential (2).

"To appreciate why the nation's hinterlands developed "their dependent relationship to this industry heartland, "one must understand the sequence of stages through which

"the national economy has evolved(1).

"Throughout the evolution... two factors, great migra-
"tions and major changes in technology, have particularly
"influenced the location of relative growth and decline.
"Both factors have repeatedly been given specific geographi-
"cal expression through their relationship to resource pat-
"tern. Great migrations have sought to exploit resources
"that were newly appreciated or newly accessible within the
"national market. Usually... the new appreciation or acces-
"sibility has come about, in turn, through some major tech-
"nological innovation(3).

"Several stages (1) of "natural ressources that count"
"can be cited in the history of the American economy. In
"the agricultural period, the natural endowment most valued
"was arable land with environmental components of climate
"and water. During industrialization, a new set of mineral
"resources became important. In the twentieth century, ser-
"vice activities and amenity resources have exerted an in-
"creasing strong pull on industry and people, along with re-
"gional differences in governmental expenditures... In each
"case, the basic conditions of regional growth were set by
"the heartland. It served as the lever for successive deve-
"lopment of newer peripheral regions by reaching out to them

"as its input requirements expanded, and it thereby fostered "specialization of regional roles in the national economy. "The heartland experienced cumulative urban-industrial spe- "cialization, whereas each of the hinterland found its com- "parative advantage based on narrow and intensive speciali- "zation in a few resource subsectors, diversifying only when "the extent of specialization enabled the hinterland region "to pass through that threshold scale of market necessary to "support profitable local enterprise. Flows of raw mate- "rials inwards and finished products outward articulated the "whole.

"Since 1950, growth of the service sector, increase in "the numbers of "footloose" industries, rapid emergence of a ""quarternary" sector of the economy expansion and inter-re- "gional migration of the nonjob-oriented population, rising "governmental expenditures and overall rising real incomes "all have served to produce yet another transformation of "the economy.... and of the traditional export - base con- "cept of hinterland growth. Advantages for economic growth "have been found around the "outer rim" of the country, in "former hinterland regions, as changing communications tech- "nology has reduced the time and costs involved in previous "heartland-hinterland relationships. The changes have been "cumulative : regional growth within the context of the na-

"tional pattern of heartland and hinterland has brought the-
"se regions to threshold sizes for internal production of a
"wide variety of goods and services at the very time that
"changes in the definition of urban resources made possible
"their rapid advance, free of the traditional constraints of
"heartland-hinterland leverage".

This analysis of the changing of economic development and population distribution does indeed reveal very plausible large scale mechanisms. It seems possible that there are two areas however, where largely stochastic elements become important. Firstly, in the "outer rim" of the country the exact location of investment will depend to some extent a unpredictable elements and the growth and interaction of these centres must therefore be a mixture of chance and economic necessity, and the precise pattern of emergent outer centres is certainly not determined a priori. Secondly, the perception of higher returns on investment in outer regions can be over or under communicated and the real returns modified accordingly, bading to different growth patterns and emergent structures. There are the sorts of effects that we agree to be able to examine using one model.

III. THE CHANGING RELATIONSHIPS BETWEEN URBAN AND REGIONAL GROWTH.

"In each of the stages (described above), urban growth "and regional development have been closely interdependent.

"America's oldest cities were mercantile outposts of a "resource area whose exploitation was organized by the deve- "loping metropolitan system of Western Europe. The initial "impulses for independent growth came at the end of the "eighteenth century, when towns were becoming the outlets "for capital accumulated in commercial agriculture and the "centers of colonial development of the continental inte- "rior. Arable land was the resource that counted in regio- "nal growth. Regional economies developed a certain arche- "type : a good deepwater port as the nucleus of an agricul- "tural hinterland well adapted for the production of a sta- "ble commodity in demand on the world market.... The proto- "typic American metropolis thus was a port at a strategic "location on long-distance oceanic or riverine trade routes, "providing a range of mercantile services and determining "the terms of trade. This agricultural resource-dominated "(but city-centered) expansion of the economy set the stage "for subsequent developments by establishing a geography of "markets, transport routes, and labor forces that conditio-

"ned the nature of succeeding growth.

"New resources became important from 1840-1850 on "wards, and new locational forces came into play. Foremost "was growing demand for iron, and later steel, and along "with it rapid elaboration of productive technologies. Jux- "taposition of coal, iron ore, and markets afforded the im- "petus for manufacturing growth in the northeastern United "States, localized by both factors in the physical environ- "ment (minerals) and environment components created by prior "growth of the urban system (linkages to succeeding stages "of production, in turn located closer to markets). The ""heartland" of the American manufacturing belt developed "westwards from New York in the area bounded by Lake Supe- "rior iron ores, the Pennsylvania coalfields, and the capi- "tal, entrepreneurial experience, and engineering trades of "the northeast, while at the same time New York cemented its "dominance by accentuation of its financial, entrepreneu- "rial, and specialized manufacturing roles. This heartland "became not only the heavy industrial center of the country, "but has remained the center of national demand, determining "patterns of market accessibility ever since.

"The heartland had initial advantages of both excellent "agricultural resources and a key location in the minerals

//

"economy. With development, it grew into the urbanized cen-
"ter of the national market. Subsequent metropolitan growth
"took place in a national pattern organized around this na-
"tional core region until after the Second World War.
"From 1869 to 1950 there was for example, a stable pattern
"of growth in manufacturing employment among the states.
"Continued spread of population and agriculture over the
"continent pulled processing and servicing activities and
"new urban growth with them. However, the developmentally-
"dominant effects still came from growth of the minerals
"economy until well into the twentieth century, so that a
"process of "circular and cumulative causation" (4) streng-
"thened and maintained the relations of the national heart-
"land and hinterland of core and periphery, and the new me-
"tropolitan centers that did emerge did so in sequence with
"the overall growth, outward spread, and spatial integration
"of the economy.

"Since 1950, advantages for economic growth have been
"found in former hinterland regions.... A good example of
"this is the explosive metropolitan growth of the South,
"Southwest, and West. We have already noted the rapid rise
"of the service and quaternary sectors of the economy and
"the rising significance of both governmental expenditure
"and amenity resources in the new growth nexus.

"Under these conditions, it is now clear that large urban "regions (whether located in the heartland or the hinter-"land) can free themselves of narrow export dependency, as "traditionally defined. The long-run viability of any large "metropolitan area, in these new conditions, resides ultima-"tely on its capacity to invent and innovate, i.e. to create "new rapid-growth high-wage activities.

"The outcomes of this latter stage of urban regional "growth is that it is now possible to interpret the spatial "structure of the United States (5) in ways that will empha-"size a pattern consisting of one, metropolitan areas and "two, the inter-metropolitan periphery".

We have seen above (§1) that a first level of increasing spatial disequilibrium could be located in the relationships between city-center and suburbs. Here appears a second level of increasing spatial disequilibrium : the growing gap between metropolitan areas and the inter-metropolitan periphery.

"Economically (5), the inter-metropolitan periphery in-"cludes most redevelopment assistance... They have a dis-"proportionately large share of low-growth and declining in-"dustries and a correspondingly antiquated economic structu-

"re. Demographically, the inter-metropolitan periphery has "been subjected to a long-term, continuous decline. This "trend reflects the movement of people to cities, especially "to the large metropolitan concentrations. Although the "smaller cities on the periphery have to some extent benefi- "ted from migration, their gains have been less, on the ave- "rage, than for all urban areas. In addition, migration "from economically depressed regions has been highly selec- "tive so that the age distribution of the remaining popula- "tion has become polarized around the very young and the ve- "ry old.... Socially, the standard indices of education and "health are substantially lower along the periphery than in "metropolitan areas. The quality of public services has "deteriorated (though their per capita cost has increased), "the housing stock is older and the level of educational at- "tainment is significantly below the average of metropolitan "America. Rapid and selective outmigration, a declining "economic base, the burden of an aging population, and low "incomes have rendered many peripherical communities help- "less in their desire to adapt to changing circumstances in "the outside world. The remaining population is frequently "short both on civic leadership and hope. They can neither "grasp the scope of events that have overtaken them nor are "they capable of responding creatively to the new situa- "tions.

"The link between self-sustaining innovation in metro-
"politan regions and growths in regions not able to attain
"the threshold conditions for self-sustaining growth is
"clear. Larger urban regions (6) combine a favorable indus-
"try mix for growth with a steadily declining share of the
"various growth industries.... High wage rates of the inno-
"vating area, quite consonant with the high skills needed at
"the beginning of the learning process, become excessive
"when skill requirements decline, and the industry (or parts
"of it) "filters down" to the smaller, less industrially so-
"phisticated regions where the cheaper labor can meet the
"declining skill demands for the filtering industry, thus
"creating the phenomenon of small towns with low-wage, slow-
"growth filtered-down industry (at the time when the metro-
"polis has moved on to new bases). "The heartland-hinter-
"land lever for growth (1) is thus replaced by the mecha-
"nisms of filtering on a regional scale. This possibly can
"produce convergence and integration of the space economy;
"however, far more likely is a circular and cumulative pro-
"cess that leads to the innovating area's spiraling away in
"terms of aggregate growth and incomes, leaving a continuing
"lag in the peripherical region that only new growth centers
"can begin to bridge. At sufficient scale, local markets,
"infrastructure, and residentiary development thus make the
"large metropolitan region self-generative of growth. When

"threshold conditions are reached, however, the metropolis "grows at about the rate of the nation. This threshold...is "likely to be a regional population of at least 1,000,000. "Beneath this scale, growth in the periphery is related to "capturing a share of downward-filtering industry, slow in "growth and yielding lower returns".

CHAPTER 2 - THREE LEVELS OF MODELLING THE SPATIAL STRUCTURE OF THE UNITED STATE.

The analysis of the evolutionary processes which are in play leads us to see the need for (at least) three levels of application of our models, organized in a hierarchy :

- the national level will consider 11 regions
- the regional level will take one of the regions and study its internal organization into 32 BEA economic Areas.
- the intra-urban level will take one of the BEA Economic Areas and study its internal organization in city-center and suburbs.

I - THE NATIONAL LEVEL.

At the national level, the interesting movements to study are the long-range and long-term growth patterns :

- regional growth within the context of the national pattern of heartland and hinterland, progressively bringing regions to threshold sizes for internal production of a wide variety of goods and services. Here, the location criteria of the long range exporting industrial activities will be the main structuring factor of the

spatial organization;

- migration of active population and more recently of non-active population.

The country will be divided into eleven regions, corresponding to the nine census and geographic divisions of the United States (Fig.2.1.):

heartland :

North-East : New England
Middle Atlantic

North-Central : West North Central
East North Central

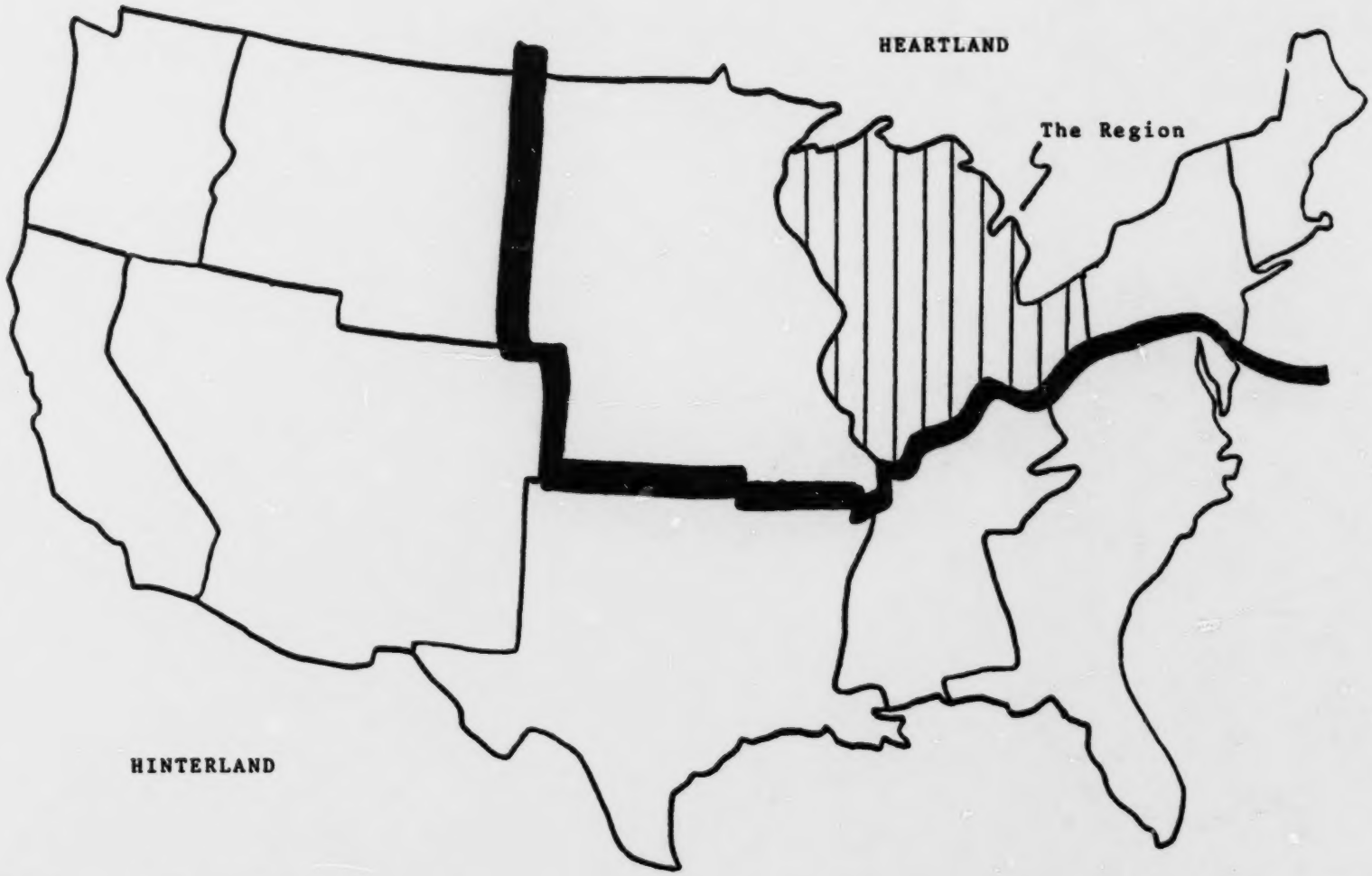
hinterland :

South : South Atlantic
East South Central
West South Central

West : North Mountains (Idaho, Montana, Wyoming)
South Mountains (Nevada, Utah, Colorado, Arizona, New Mexico)
North Pacific (Washington, Oregon)
South Pacific (California).

The study will be developed in two phases :

FIGURE 2.1. THE NATIONAL LEVEL



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I.A. - Analysis of the real spatial growth patterns.

This first phase will be performed at the state level. It involves the definition of the variables relevant to the problem :

- the carrying capacity of each state : employment in agriculture and mining.
- two variables of population : .
  - active population
  - non-active population
- a certain number of economic variables which have not been specified yet :
  - production and distribution of goods and services in frequent demand - elementary local activities (due to the growth of each state).
  - prouduction and distribution of goods and services in less frequent demand - rare local activities (due to the exchanges between states).
  - exporting activities (due to the exchanges between the country and the outside world).

The method used for defining these different types of economic variables is inspired from the minimum requirement technique (7). After having grouped the states according to their degree of urbanization, the structure of employment of each state is computed (percentage of each type of activity

in the total employment). The minimum percentage observed in each type of activity, for each group of states, is then considered as the minimum required for survival at that size. It is the internal part of the activity. The surplus is considered as the sum of the long-range part, due to the exchange between states, and the exporting part. An estimation of the employment due to the exchange with other countries leads to the definition of the exporting part and the breaking up of this sum.

The different types of activities will be the following :

- raw material oriented manufacturing activities
- market oriented manufacturing activities
- "foot loose" manufacturing activies
- wholesale trade
- retail trade
- transportation, communication, public utilities
- finances, insurance, real estate
- business and repair services
- personal services
- professional and related services
- public administration

A final regroupment, according to the main location criteria, will lead to the consideration five or six economic va-

riables.

This computation will be done for three points in time -1930, 1950 and 1970- so that it will be possible to catch up the heartland-hinterland relationship and its recent transformation.

Spatial growth patterns of each of the variables will be analyzed.

I.B. - Modelling and simulating change.

In the second phase, the states will be regrouped into the 11 regions mentioned above. From the study of the growth patterns will come out the basic parameters influencing growth during the 1930-1970 period, permitting to build up the equations of the model. From there on, by iteration, simulations and successive adjustments of the model will hopefully lead us to an acceptable reproduction of the past. Possible trends for the next twenty years can then be explored on the basis of various hypotheses concerning the evolution of the main parameters of the model and the total rate of change of the variables at the national level.

II - THE REGIONAL LEVEL.

We have seen that the heartland-hinterland lever for growth, operating on the national scale, has been recently replaced by mechanisms of filtering on a regional scale. The distinction between self-generative metropolitan America, and the hand-meadown inter-metropolitan periphery, is that the latter is condemned to progress characterized at best by lagged emulation and secondhand growth.

At the regional level, the interesting movements to study are then the movements of activities and people which reorganize the hierarchy of daily commuting zones (daily urban systems - "D.U.S.") inside the region.

"As Berry says (1), "Each D.U.S. specializes, of course, "in the production of certain goods and services in order to "take advantage of lower costs of production resulting from "the availability of natural resources, and from benefits to "be derived through location and through internal and exter-"nal economies. Each also approaches self-sufficiency in "its residentiary industries; that is, most of the services "and some of the goods required by the household sector and "by local business as intermediate products are produced wi-"thin the area. Thus the "D.U.S." corresponds to the closed

"trade areas of central place theory, in which the number "and type of establishments and their size and trade areas "are bounded by the relative transportation costs from hin- "terland to competing centers. In other words, the closure "with respect to residentiary industries includes general "and convenience retail and wholesale trade activities and "those other services which are difficult or impossible to "transport and are most efficiently consumed in the vicinity "of their production. On the other hand, the economic areas "are open for the most part to the movement of transportable "commodities and nontransportable special services, such as "education, recreation, as well as to the effects of federal "investment".

A good approximation of the D.U.S. is given by the BEA Economic Areas.

As a test for a second model, we have chosen a highly urbanized region in contact with wide rural areas and undergoing internal selective growth and decline : the East North Central Region (fig.2.2). It included, in 1960, 32 BEA Economic Areas, covering a spectrum of population ranging from 210,000 inhabitants (Eau Claire, Wis.) to 8,193,000 inhabitants (Chicago, Ill).

Here again, the study will be developed in two phases:

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II.A. Analysis of the real spatial growth patterns at the BEA level.

It involves the definition of the variables relevant to the problem

- the carrying capacity of each BEA : employment in agriculture and mining
- two or three groups of population, defined by their socio-economic status (income, education, professional status...)
- a set of economic variables.

In this matter what was predicted by the first model, i.e. essentially the change in long-range local activities at the national level, will be taken here as given. So the sum of employment in exporting activities to other countries and rare local activities will be considered this time as the exporting sector. On the other hand, what was considered previously as the elementary local activities of the region will be broken into two categories, defined by the same method inspired by the "minimum requirement technique" :

- the rare local activities, due to the exchanges between BEA
- the elementary local activities, due to the internal growth of each BEA

This computation will be done for three points in time - 1930, 1950 and 1970. A problem of availability of data may arise here. If we cannot go far enough in the past with BEAs, we will take SMSAs as spatial units.

Finally, the main spatial growth patterns of each of the variables will be recognized and analyzed.

II.B. - Modelling and simulating change.

Since variables, location criteria and growth patterns will be essentially different from the ones recognized at the national level, other basic parameters will appear and an entirely new model will have to be conceived. By iteration, simulations and successive adjustments of this new model, we will try to reproduce the past evolution and prospect the years in front of us.

III. THE INTRA-URBAN LEVEL.

The same study design will be applied to one of the BEAs of the same region, in order to explore the dynamics of that fundamental increasing disequilibrium we have described in the first pages of this report.

IV. CONCLUSIONS

From the point of view of the planner, there will be, we hope, interesting insights coming out of this study design.

First of all, it is obvious that each level described has its own logic. But it might be interesting to see how mechanisms vary from one level to another and if there is any logic also in this variation in scale.

Second, the things predicted by each model will be different, so that we could expect to gasp some information about the level of action relevant to each kind of problem, which is a basic planning concern.

Third, in a more practical way, each level will define the degree of detail required for predictions relevant to this level.

PART TWO :

FURTHER RESEARCH ON THE MODELLING OF INTRA-URBAN CHANGE

CHAPTER 3 - A SEVEN VARIABLE MODEL

This version of the intra-urban model differs from the previous ones, mainly by the addition of one variable. The model now contains seven variables which are respectively, for the employment sectors, exporting industry, exporting tertiary activities, elementary local services, rare local services, local industry and, for the population, the "blue-collar" residents and the "white-collar" residents. In the preceding versions of this model we have not explicitly considered local industry. While studying the case of a Belgian city "Liège", we attempted to aggregate in a single variable both local industry and rare local services, but as their locational criteria are too different, they must be considered independently.

Before describing the equations of this seven-variable model, let us try to get some insight into what we have called the "urban actors".

I. THE FUNDAMENTAL BEHAVIOURS OF THE URBAN ACTORS

I.A. THE DEMAND SIDE.

Each individual has a whole spectrum of needs he satisfies at different frequencies: he eats bread every day, practices a sport once a week, goes to the theater once a month, buys a painting every three years, needs education at a period of his life. Thus he regularly consumes goods and services. This is the demand side.

Of course, the demand varies from one person to another but statistically consumption patterns may be recognized and related to the income of people, to their age (and the size of their family) and to their cultural background. Therefore it is possible to devide the population into different groups which are characterized by different average behaviours.

The way these groups of residents are made up depends on the problems one wants to analyze. In our present case, we have so far essentially explored the influence of people's socio-economic status on the city structure. This is the reason why we have considered two groups of residents mainly differenciated by their income : the white-collar residents and the blue-collar residents.

The white-collar residents, who mainly work in the tertiary sector, earn relatively high salaries which make them less sensitive to the price of things. Therefore they consume more goods and services, more space, live in more expensive housing, like more expensive neighbourhoods located far from heavy industries. The importance they pay to the cost of transportation is relatively small which renders them highly mobile.

The blue-collar residents mainly work in the secondary sector (exporting and local industry) and their income is lower. Their sensitivity to the price of things is higher : they consume less goods and services, less space, live in cheaper housing and their mobility is lower. Therefore their power on space is considerably smaller; they do not choose; they take what is left.

I.B. THE SUPPLY SIDE.

The economic infrastructure of a society is the response to this demand from the supply side :

- activities of production of goods (the primary and secondary economic sectors) which have very specific location criteria imposed upon by their structure of production costs.

- activities of production of services and distribution of goods (the tertiary economic sector) which bring to people, anywhere they are located, all the necessary services and goods that have been produced elsewhere.

a) Tertiary functions.

To each one of the needs of the population corresponds one or more tertiary functions : in the example we have taken, they are the sale of bread, sports equipment and paintings but also schools of different kinds, sport halls and theaters.

The number of distribution points of each function in space depends on the frequency of satisfaction of the corresponding need. If it is a good, it depends also on its degree of perishability. Thus bread in Europe is a perishable good frequently eaten by everybody and needs to be bought every day. Therefore a small number of families can support the existence of a bakery whose potential hinterland can be small. Sports equipment, not frequently used and only by a part of the population, induces a much smaller number of distribution points because each of them has to be supported by a much larger number of families. The potential hinterland of such a function is much bigger.

The technological means which are used to produce a good have also an influence on the number of distribution points. For instance, the very frequent need of eating bread has induced a whole network of bakeries. Now that it is possible to stock bread in a deep-freezer, it is not necessary anymore to buy it every day. On can buy it once a month with all the other "unfrequent goods". The function of selling bread has jumped up in the hierarchy of tertiary functions.

Thus frequent consumption of goods and services induces proximity of distribution points; rare consumption decreases the number of distribution points and increases the distance between them. To the spectrum of the population needs corresponds a spectrum of tertiary functions, each of which having a specific population supporting threshold.

In our model, we have grouped all the tertiary functions into three different types.

The elementary local functions, that we have also called short-range functions, respond to all the daily needs of people. They have small hinterlands and follow the population in all its moves. They are the local supermarkets, primary schools, post-offices, cleaning services, garages,

ordinary eating places, local banks,....

The rare local functions, we have also called long-range functions, group services and goods that are less frequently needed : furniture shops, travel agencies, nice restaurants, high schools, small hospitals, theaters, nice clothing shops, car dealers,... Their hinterland is much bigger but still local and therefore they need to be located on good transportation axes. They follow less easily the movements of the population.

The exporting tertiary functions group very rare services and goods : high style clothing, specialized hospitals, universities, highly specialized or luxury shops, regional administrative functions, offices of all kinds... Their population supporting threshold is always much bigger than the population of the city; they need the support of the rural areas to be able to exist. They are the essence of the C.B.D. and give the city its regional role.

All these functions aggregate in space, forming a whole hierarchy of commercial and service centers.
Where only elementary functions exist, we find small neighbourhood centers that can take the form of an aggregate of specialized shops or the one of a small integrated shopping

center.

Where rare functions locate, we find also elementary functions, the sum of them constituting a community center which again can take the form of an aggregate of specialized shops or the one of a bigger shopping center grouping everything in one building.

In the C.B.D., we find the three types of tertiary functions.

In our model, we did not paid any importance to the way functions aggregate (specialized shops or shopping centers); we only considered the number of jobs they put on the labor market.

b) Industrial functions.

Economists generally consider the industrial activities as raw-material oriented, market-oriented and intermediate. Talking about the internal structure of the city, we will use another grouping based on the spatial origin of the demand.

Exporting industry is induced by a demand external to the city; it happens to locate there either by chance or because of the existence of a site of regional or national

importance (main transportation axis, mineral stratum,...). Its ties with the city are not very important. Nevertheless, it is quite sensitive to the characteristics of the urban space : these large factories generally need much cheap land and good transportation facilities to the outside world. Originally located in the center (they even often created the city) they have a tendency to decentralize when the density increases too much. It is often through them that the urban space organizes its structure.
They can be raw-material oriented, market-oriented or intermediate, depending on the structure of their production costs.

Local industry, on the contrary, is induced by a local demand coming from the residential population and the exporting industry. It therefore is market-oriented almost by definition. It often consists of smaller units of production, consumes less space per worker and is therefore less sensitive to density or price of the land. Transportation is less essential for it.

Exporting and local production activities are often integrated in the same units of production. Here again our model does not pay any attention to the way these activities are funtionally organized. It is only concerned with the

number of jobs induced by external and internal demands.

I.C. SPATIAL INTEGRATION OF DEMAND AND SUPPLY IN THE CITY

These seven basic urban actors interact with each other and with the characteristics of the urban space they have produced by their aggregation, in very complex ways. It takes the form of a long negociation from the initial state which aims at winning the maximum number of locational advantages. However, some urban actors are more powerfull than others (i.e. have more money); they are the ones which prescribe the rules. The less powerfull ones take what is left.

We will see through the simulations that the resulting urban structures are rarely optimal for everybody; they are the spatial expression of a struggle for economic power.

II. DESCRIPTION OF THE NEW VERSION OF THE INTRA-URBAN MODEL

There are two main innovations in this new version of the intra-urban model : the addition of a seventh variable and the variation of the external demand.

As we said earlier, we have felt the need of splitting the previous so-called "long-range services" into two variables : the rare local tertiary functions and the local industry. Indeed, the demand of long-range services comes only from the consumers (the local population) and its cooperativity is only internal. Whereas, the demand of local industry comes not only from the population but also from exporting industry and its cooperativity is not only internal but also related to the presence of the exporting industry and the exporting tertiary activities.

The second modification of this version concerns the external demand. Now we have considered that the external demand for industry and for the tertiary sector is a function of the size of the city which itself is related to the size of its hinterland. The form of the expression comes from observations on the relation between external demand and the size of Belgian and American cities (see Appendix 1). This is one possible scenario; other hypotheses can be made.

The external demand for the function L is now :

$$D^L = \sqrt{(d^L)^2 + \gamma^L P_T}$$

where d^L is a constant related to the economy of the region.

The parameter γ^L expresses how the external demand for the function L is influenced by the size of the city which is given by P_T (total population of the system).

The equations expressing the evolution in time of the different variables at each point of the system become now :

exporting industry

$$\frac{dS_J^1}{dt} = \varepsilon^1 S_J^1 \left(1 - \frac{S_J^1}{\frac{D^1 A_J}{\sum_{J'} A_{J'}}} \right)$$

with

$$A_J = \left(\frac{1 + \varrho^1 S_J^1}{\mu^1 + \alpha_J \phi^1} * \frac{\tau^1}{\tau^1 + P_J^t} \right)^{CO^1}$$

where P_J^t is related to the price of land at the point J :

$$P_J^t = \sum_{L'=1,7} \gamma^{L'} S_J^{L'}$$

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exporting tertiary activities

$$\frac{dS_j^2}{dt} = \varepsilon^2 S_j^2 \left(1 - \frac{S_j^2}{D^2 \frac{A_j}{\sum_{j'} A_{j'}}} \right)$$

with

$$A_j = \left(\frac{1 + e^{2,2} S_j^2 + e^{2,7} S_j^7}{\mu^2 + \alpha^* \phi^2} \times \frac{\tau^2}{\tau^2 + P_j^t} \right)^{\omega^2}$$

We have considered that the attractivity of a location for exporting tertiary may be affected in some cases by the easy availability (access) of their employees.

elementary (L = 3) and rare (L = 4) local tertiary functions

$$\frac{dS_j^L}{dt} = \varepsilon^L S_j^L \left(1 - \frac{S_j^L}{\sum_{j'} \frac{\sum_{l' \neq 7} \beta^{ll'} S_j^{l'}}{\mu^L + \phi^L \delta_{jj'}} \times \frac{A_{jj'}}{\sum_{j^*} A_{j'j^*}}} \right)$$

where

$$A_{jj'} = \left(\frac{1 + e^L S_j^L}{\mu^L + \phi^L_{jj'}} \times \frac{\tau^L}{\tau^L + P_j^t} \right)^{\omega^L}$$

The induction rate $\beta^{ll'}$ of the function L by the population l can now be related to the income of the population l'. Generally it has been observed that white-collar residents consume more on the average than blue collar residents.

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local industry.

$$\frac{dS_j^5}{dt} = \varepsilon^5 S_j^5 \left(1 - \frac{S_j^5}{\sum_{j'} \frac{\nu^1 S_j^1 + \sum_{l' \neq 1} \beta^{5l'} S_j^{l'}}{\mu^5 + \phi^5 \delta_{jj'}} \times \frac{A_{jj'}}{\sum_{j''} A_{j''j'}}} \right)$$

with

$$A_{jj'} = \left(\frac{1 + \rho^{55} S_j^5 + \rho^{51} S_j^1 + \rho^{52} \delta_j^2}{\mu^5 + \phi^5 \delta_{jj'}} \times \frac{\tau^5}{\tau^5 + P_j^t} \right)^{col}$$

blue-collar (l = 6) and white-collar residents (l = 7).

$$\frac{dS_j^l}{dt} = \varepsilon^l S_j^l \left(1 - \frac{S_j^l}{\sum_{j'} \sum_{l'} \zeta^{l'l} S_{j'}^{l'} \frac{\mathcal{R}_{jj'}}{\sum_{j''} \mathcal{R}_{j'j''}}} \right)$$

with

$$\mathcal{R}_{jj'} = \left(\frac{1 + \sigma^l S_j^l}{1 + \eta^l S_j^1} \times e^{-b^l \delta_{jj'}} \times \frac{\tau^l}{\tau^l + P_j^t} \right)^{col}$$

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In this equation we have introduced a term in the residential attractivity that takes into account the fact that residents may prefer not to live near heavy industry. This term is ($1 / (1 + \eta^{L} S_{3}^{1})$).

III. VALUES OF THE PARAMETERS AND DEFINITION OF THE GLOBAL INDICES CHARACTERIZING THE SPATIAL STRUCTURES.

III.A. Choice of the values of the different parameters.

For these theoretical simulations we have based the evaluation of some parameters on a study we made of the spatial distribution of employment and residents in Liège and on general norms in use in Belgium.

1) We have chosen the spatial requirement of an employment or of a resident in agreement with the Belgian averages or norms which are :

at the location of the jobs :

- exporting industry : 210m^2/employment
- exporting tertiary : 15m^2/employment
- elementary local tertiary : 70m^2/employment
- rare local tertiary : 70m^2/employment

at the location of the residents :

- blue-collar residents : 50m^2/actif
- white-collar residents : 70m^2/actif

+) The unit of length is km and 1 unit of the variables represents 10 employments or 10 residents.

and thus

γ^1 : .0021+), γ^2 : .00015, γ^3 : .0007, γ^4 : .0007,

γ^5 : .001, γ^6 : .0005, γ^7 : .0007

2) For the parameter $\zeta^{L'L}$ which represents the percentage of people of type L working in the sector L' we have taken the values for the Province of Liège(1) which are :

	Percentage Blue-collar	Percentage White-collar
- for exporting industry	96%	4%
- for exporting tertiary	37%	63%
- elementary local tertiary	38%	62%
- rare local tertiary	30%	70%
- local industry	70%	30%

$\zeta^{1,6}$: .96 $\zeta^{1,7}$: .04 $\zeta^{2,6}$: .37 $\zeta^{2,7}$: .63 $\zeta^{3,6}$: .38 $\zeta^{3,7}$: .62 $\zeta^{4,6}$: .3 $\zeta^{4,7}$: .7 $\zeta^{5,6}$: .7 $\zeta^{5,7}$: .3

3) Based on some investigations of family budgets for the Province of Liège(2) we have been able to deduce an average value of the ratio of the consumption of white-collar workers to the consumption of the blue-collar workers. This ratio has an average value of 1.33. From data of the city much employment in the sector L' is induced by the consump-

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tion of population L' (parameter $\beta^{LL'}$).

A blue-collar worker induces .1074 employment in the elementary tertiary and a white-collar worker induces .1429 employment in this sector (see Appenix 3 for the details of the calculus).

As the parameter β in our model expresses the rate of induction of an employment L by the population k at unit price for the transportation cost, we must weight these values by a transportation cost.

We can also obtain an approximate value for how much employment is induced by the population for the rare services and the local industry.

This leads us to choose the following values for :

$\beta^{3,6}$: .25 $\beta^{4,6}$: .20 $\beta^{5,6}$: .03

$\beta^{3,7}$: .32 $\beta^{5,7}$: .25 $\beta^{5,7}$: .12

Also as well as the induction by exporting industry of employment among local industry, (see Appendix 4).

w^1 : .15

The other parameters of the model have been chosen in such a way as to obtain the proportion between exporting

functions and local tertiary functions which is observed in general in American and Belgian cities (see appendix 1). Of course this proportion is correlated to the size of the city.

The values of the other parameters are :

For ε^L which are related to the time characteristics of the employments L and the population L, $\varepsilon^L = .15$. The transportation cost :

$\phi^1 : .3 \quad \phi^2 : .05 \quad \phi^3 : .5 \quad \phi^4 : .05 \quad \phi^5 : .1$

The parameters CO^L, which are related to the information available to the actors themselves which influences the unanimity of their preferences, have the value : $CO^L = 10$, for L = 1 until L = 5 and $CO^L = 1$ for L = 6 and 7. The parameters τ^L which measure the intensity of the crowding supported by the function L or the population L at the point J have the value :

$\tau^1 : 4 \quad \tau^2 : 16 \quad \tau^3 : 10 \quad \tau^4 : 12 \quad \tau^5 : 9$
$\tau^6 : 13 \quad \tau^7 : 10$

The parameter ρ^L which measures the cooperativity has the values :

- the internal cooperativity of exporting industry ρ^1 : .0017
- the internal cooperativity of exporting tertiary $\rho^{2,2}$: .005 and the cooperativity between this function and the presence of white-collar residents $\rho^{2,7}$: .002
- the internal cooperativity between the elmentary local services : ρ^3 : .0035
- the internal cooperativity between the rare range services ρ^4 : .0005
- the internal cooperativity between the local industries : $\rho^{5,5}$: .0011
- the cooperativity between local industry and exporting industry : $\rho^{1 5,1}$: .0003
- the cooperativity between local industry and exporting tertiary : $\rho^{5,2}$: .0002

The parameter τ^L which expresses the affinity between the same type of population L has been chosen $\tau^6 = \tau^7 = .0005$. The parameter η^L which is related to the aversion of the population L to living near to heavy industry has the value : η^6 : .0008 η^7 : .0018

The parameter b^L which represents the importance accorded by the population L to the cost of travel in units of money b_c^L and to the cost of travel in unit time b_t^L has been chosen :

b_c^1 : .6 b_t^1 : .1 b_c^2 : .3 b_t^2 : .4

with L = 1 for blue collar residents

L = 2 for white collar residents

The external demand for exporting industry coming from the economy of the region $d^1 = 700$, and the exporting demand for exporting tertiary functions $d^2 = 400$.

The parameter α_j expresses the accessibility of the communication axis for the exporting industry.

For the parameter ν, which expresses how the external demand of the function L is related to the size of the city (which is given here by the total population of the system), we have chosen :

ν^1 : 16 ν^2 : 14

The initial values of the different variables are fixed for the center of the lattice :

S_c^1 : 280 S_c^2 : 150 S_c^3 : 80 S_c^4 : 65 S_c^5 : 65

S_c^6 : 310 S_c^7 : 310

For the other points of the lattice, we have put very small values of each variable but which are randomly determined. These values are between 1 and 3 units for the employments and 2.5 and 7.5 for the populations.

III.B. Definition of the indices characterizing the spatial structures obtained by simulation.

As in the simulations of the preceding reports, we have calculated some global characteristics of the spatial structures obtained :

DT^L : represents the total transportation mileage for the distribution of the function L (L corresponding to the local services and industry); it is the "total haulage distance"

XT^L : corresponds to the total commuting traffic (passenger miles) run daily by the population .

TM^L : for L = 3, 4 and 5, is the mean haulage distance for the local functions.

TM^L : for L = 6 and 7, is the average commuting distance for the population L.

CT^L : represents the average cost of travel for the variable L.

These global characteristics are calculated by the expressions

$$DT^L = \sum_J \sum_{J'} \frac{\sum_{L'=6,7} \beta^{L'L} S^{L'}_{J'}}{(\mu^L + \phi^L \delta_{JJ'})} \times \frac{A_{JJ'}}{\sum_{J*} A_{J'J*}} \delta_{JJ'}$$

and

$$XT^L = \sum_J \sum_{J'} \sum_{L'} \beta^{LL'} S^{L'}_{J'} \frac{R_{JJ'}}{\sum_{J*} R_{J'J*}} \delta_{JJ'}$$

for L = 3,4 and 5 $TM^L = \frac{DT^L}{S^L_T}$ for L = 6, 7 $TM^L = \frac{XT^L}{S^L_T}$

with S^L_T : total of the variable L for the whole system

$$CT^L = TM^L \phi^L \quad \text{or} \quad CT^L = TM^L \beta^L$$

We calculated two new indexes which tell us something more about the concentration of a function L in the city. They are defined as follows :

1. "Concentration index"

$$TI^L = \sqrt[4]{\sum_{J=4,NB} \left(S^L_J - S^L_T/NB \right)^4 / NB}$$

2. "Location quotient"

$$LQ_J = \left(S^L_J / S^{L'}_J \right) \times \left(S^{L'}_T / S^L_T \right)$$

with

$$S^L_T = \sum_{J=4,NB} S^L_J$$

$S^{L'}_J$ is a function different from S^L_J

IV. RESULTS OF THE SIMULATIONS

In these simulations, the groundplan of the communication axis (canal) is different (fig.3.1) from the one in the preceding intra-urban report[3]. This will affect the location of exporting industry. As this transportation axis does not pass through the center of the city, exporting industry rarely remains in the center. We observe mainly two types of location for it : concentration on a point on the communication axis, or dispersion along the communication axis. The simulations we performed show that we can obtain either result, and that furthermore the resulting urban structures are completely different both qualitatively and quantitatively.

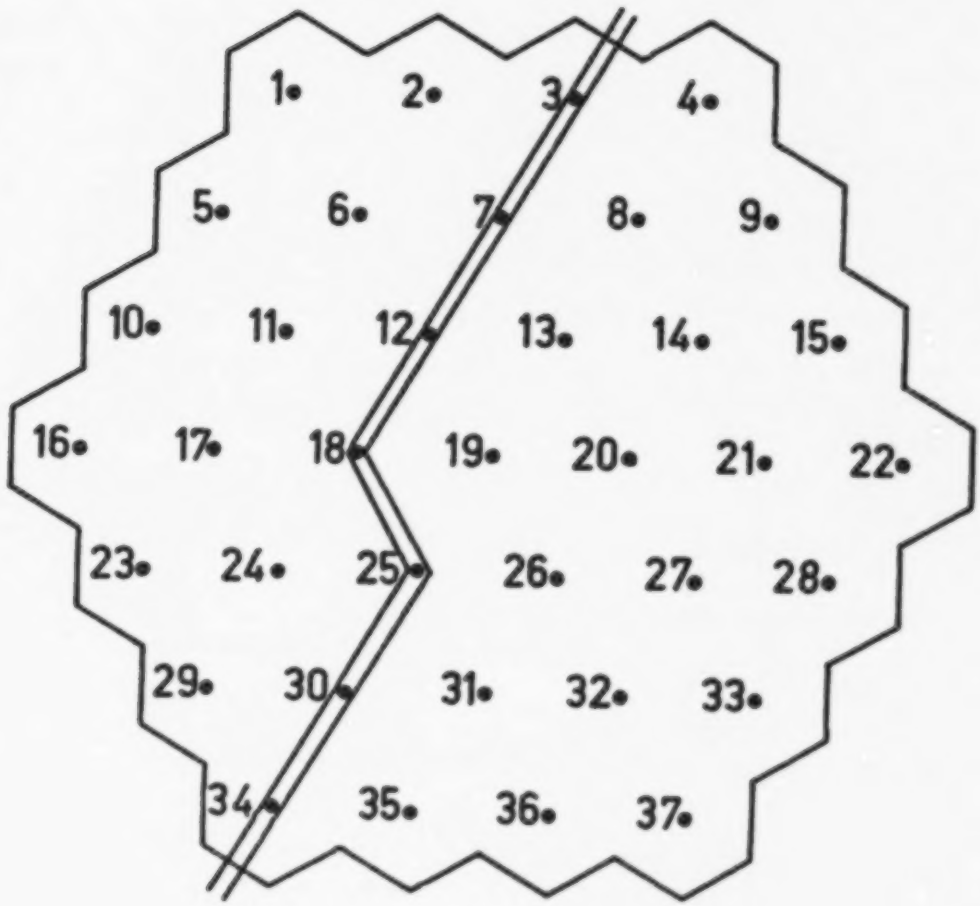
IV.A. Study of the different phases of the growth of a city

Let us analyze in detail the different phases of the growth of a city where exporting industry is going to centralize on a point of the transportation axis ($^{1}= .0017$)

Exporting industry.

At the initial time, we begin with exporting industry (S^1) mainly concentrated in the center as the other variables, but very quickly, under the pressure of a crowding

FIGURE 3.1. NUMERATION OF THE POINTS OF THE LATTICE AND SCHEME OF THE COMMUNICATIONS AXIS



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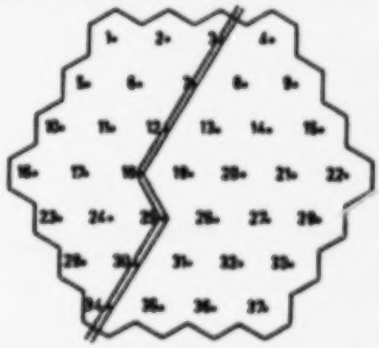
KEY TO THE FIGURES OF CHAPTER 3 (PART TWO)

THEORETICAL LATTICE



BLUE-COLLAR RESIDENTS
WHITE-COLLAR RESIDENTS

1.0 < 15.0
15.0 < 30.0
30.0 < 40.0
40.0 < 60.0
60.0 < 90.0
90.0 < 200.0
200.0 < 600.0

EXPORTING INDUSTRY

1.0 < 10.0
10.0 < 20.0
20.0 < 40.0
40.0 < 100.0
100.0 < 200.0
200.0 < 800.0

LOCAL INDUSTRY

1.0 < 10.0
10.0 < 15.0
15.0 < 25.0
25.0 < 75.0
75.0 < 120.0
120.0 < 200.0

ELEMENTARY LOCAL TERTIARY
RARE LOCAL TERTIARY

1.0 < 10.0
10.0 < 15.0
15.0 < 20.0
20.0 < 30.0
30.0 < 70.0
70.0 < 150.0

TOTAL EMPLOYMENT
TOTAL POPULATION

10.0 < 50.0
50.0 < 100.0
100.0 < 150.0
150.0 < 250.0
250.0 < 500.0
500.0 < 1000.0

LOCATION QUOTIENT

50.0 < 85.0
85.0 < 95.0
95.0 < 100.0
100.0 < 110.0
110.0 < 130.0
130.0 < 800.0

TOTAL DENSITY

50.0 < 100.0
100.0 < 150.0
150.0 < 200.0
200.0 < 400.0
400.0 < 1000.0
1000.0 < 1500.0

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effect, it leaves the center and spreads out along the canal (t = 50) (fig.3.2), with the greatest concentration of this function on points 7 and 30. At t = 200 units, the parameter ρ^1, which expresses the internal cooperativity of this type of employment, begins to play a more important role and induces the concentration of almost all exporting industry on a point, which is for this simulation in the South of the lattice.

In figure 3.3, we see the evolution over time of the percentage of employment in exporting industry for some particular points on the transportation axis (points 7, 25 and 30). We observe after t = 50 units the major growth of this employment on points 7 and 30 which are the farest away from the center and secondly at t = 200 units a strong polarization of the growth on the point 30 and the decrease of the industrial employment on point 7.

As we shall see in the following chapter, other slightly different initial values of the different variables can give rise, for the same set of parameters, to a structure where exporting industry is concentrated in the North of the lattice. Thus while final polarization is a stable result,

FIGURE 3.2. EVOLUTION OF THE DISTRIBUTION OF EXPORTING INDUSTRY (s^1)
(INTERNAL COOPERATIVITY OF EXPORTING INDUSTRY ρ^2=.0017)

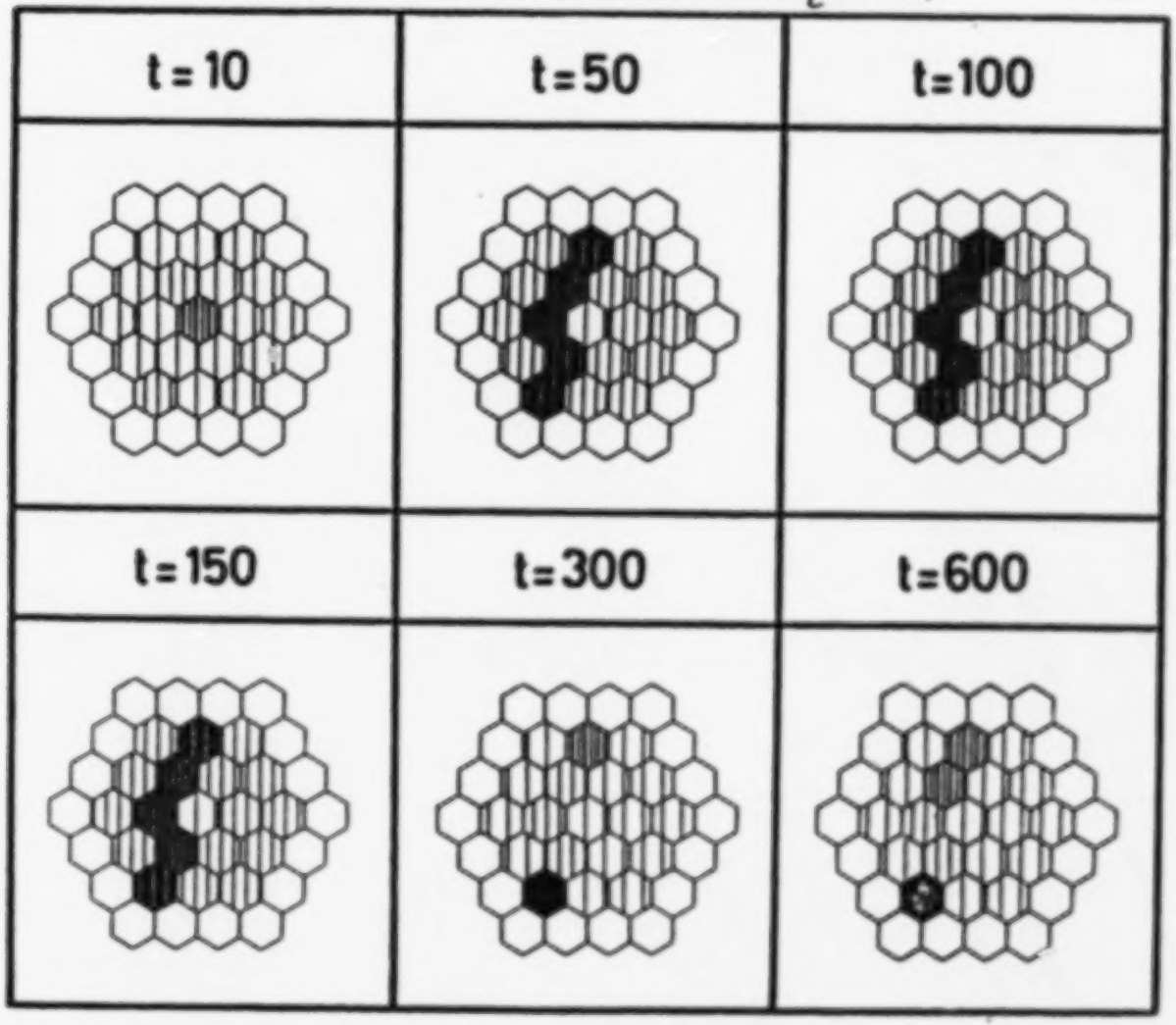

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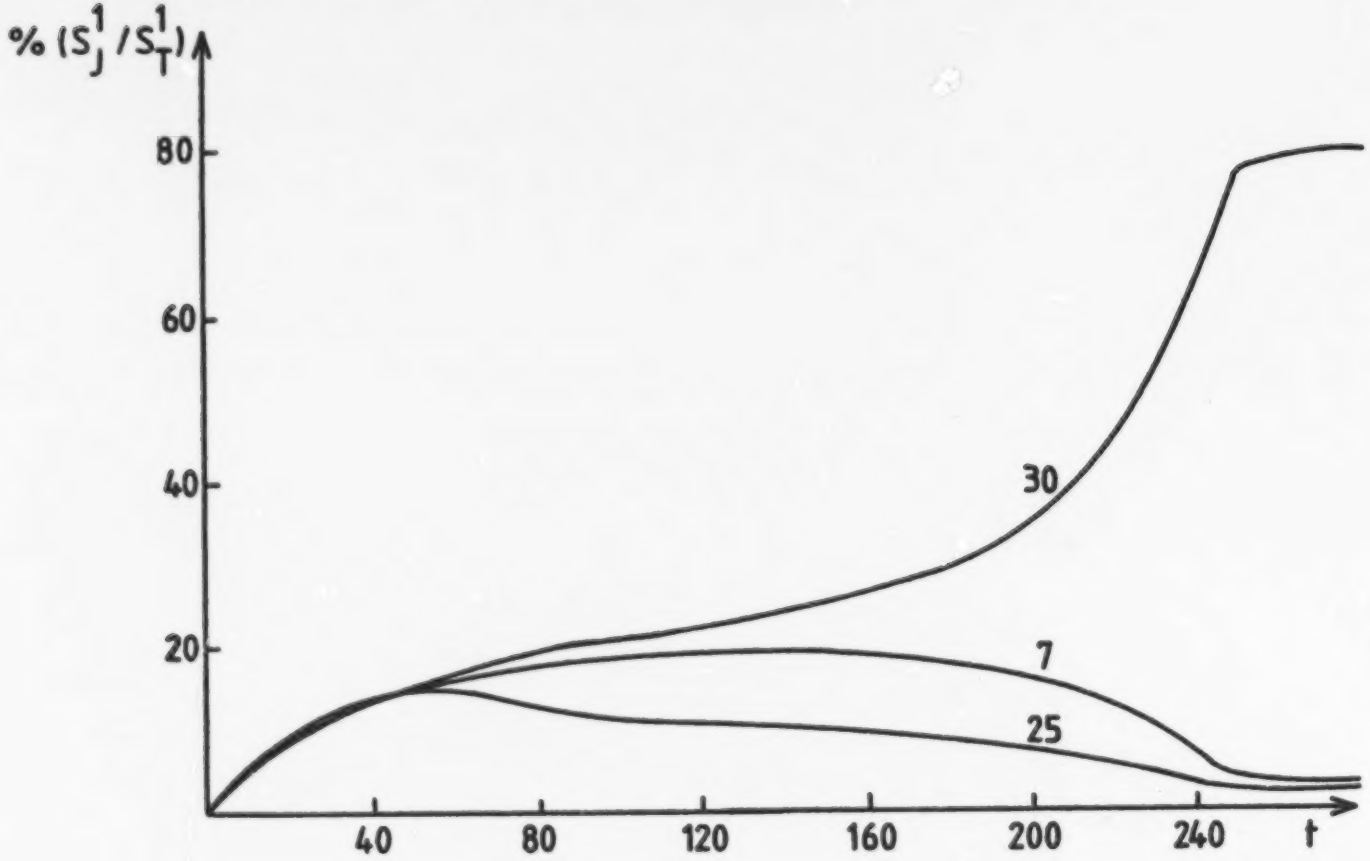
FIGURE 3.3. PROPORTION OF JOBS IN EXPORTING INDUSTRY. EVOLUTION IN TIME ON SOME PARTICULAR POINTS (7,25 AND 30)



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the precise location of the pole is not. Clearly a bifurcation occurs having branches leading either North or South.

Local industry.

As far as local industry is concerned (S^5), its location is both affected by the presence of exporting industry and also the distribution of population as its demand comes from the two. We note on figure 3.4 and table 3.1 that the strong concentration of exporting industry at the final state attracts the greatest percentage of local industry on point 30. We observe also, with the increasing value of the TI^5 index that the evolution in time of this function for the whole city is one of increasing concentration.

Exporting tertiary function.

Since in all the simulations described in this report, exporting tertiary employment is always concentrated in the center, we shall not discuss the distribution of this type of employment. Clearly, it will be interesting to study in our subsequent work, possible causes leading to decentralization of the C.B.D. and to the many and various effects this may have on the urban structure.

FIGURE 3.4. EVOLUTION OF THE DISTRIBUTION OF LOCAL INDUSTRY (S^5)

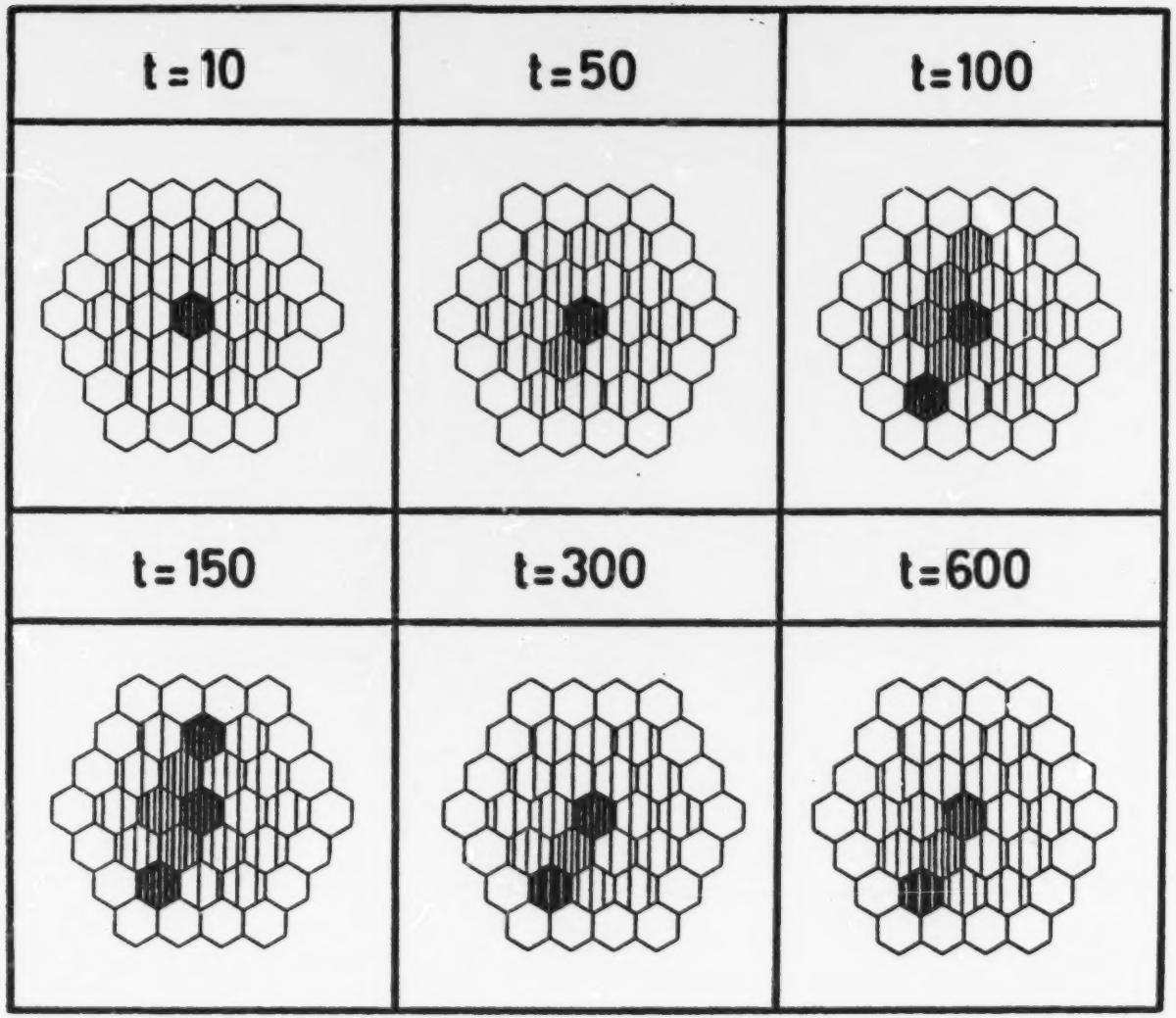

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Table 3.1. Percentage of employment in local industry against the total of this function for the whole city, for some particular points.

	% S_7^5	% S_{19}^5 (center)	% S_{25}^5	% S_{30}^5	TI^5
t = 10	2.1	56.0	2.9	2.1	--
t = 50	6.9	19.7	8.3	7.2	13.1
t = 100	9.1	17.2	7.7	11.0	15.9
t = 150	9.9	16.8	7.1	12.6	21.6
t = 300	2.3	13.5	5.8	42.1	44.5
t = 600	2.3	13.5	5.8	41.9	44.3

Elementary local tertiary functions.

As shown on figure 3.5 and on table 3.2, the spatial distribution of elementary local services is strongly influenced by that of the population. At the final state, the greatest density of population is observed on point 30 which has 22.7% of the total population although the center has only 12.8%. The greatest density of elementary local services is also observed on point 30.

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FIGURE 3.5. EVOLUTION OF THE DISTRIBUTION OF THE ELEMENTARY TERTIARY FUNCTIONS (s^3)

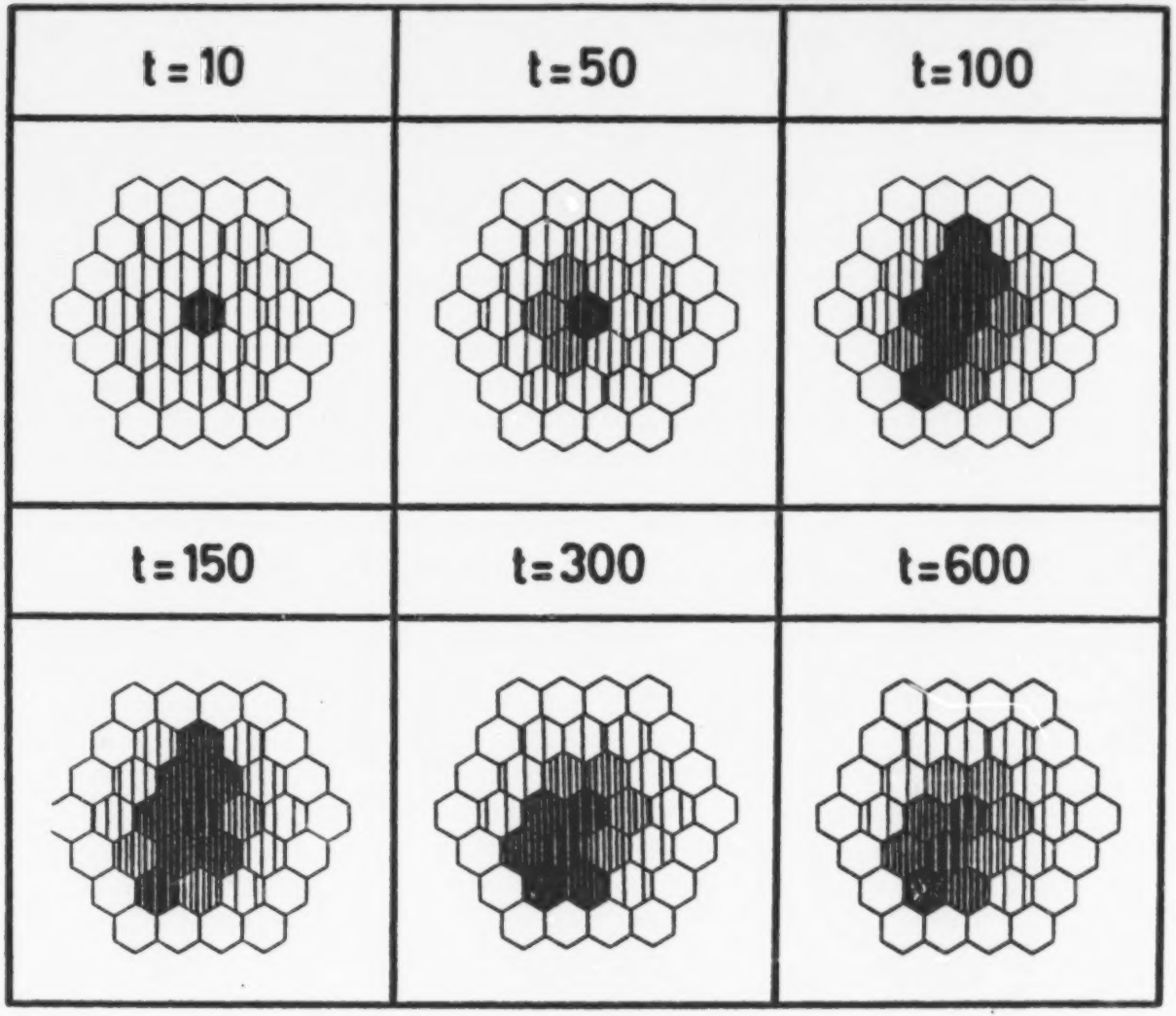

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Table 3.2. Spatial distribution of the elementary and rare local tertiary functions.

	Center	first hexagon ring	second hexagon ring	point 30
S_j^3 average value	49.7	23.8	16.7	83.3
average percentage	13%	6%	4%	22%
S_j^4 average value	54.6	23.4	12.1	25.9
average percentage	16%	7%	10%	8%

Rare local tertiary functions.

The distribution of the rare local services is less influenced by the distribution of the population than the elementary local ones, as this function is more sensitive to the pressure on land and to the good accessibility of the

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center. So we observe in figure 3.6 and in table 3.2 that the center always retains the greatest density of this employment during the growth of the city.

Blue-collar workers.

The evolution in time of the residential location of the blue-collar workers is rather strongly affected by the evolution of the distribution of exporting industry (fig. 3.7). At the final state, the greater density of blue-collar workers is observed on point 30 : s^{c}_{30} = 455 (34.7%) against 150 for the center (11.4%). This is due to the fact that 53.5% of the total blue-collar residents have their jobs in the exporting industrial sector (see table 3.3). Moreover this type of population attaches a greater importance to transportation costs than the white-collar residents.

In appendix 5, a detailed evolution of the distribution of the blue-collar residents is given, but for a structure where exporting industry is situated in the North of the lattice.

FIGURE 3.6. EVOLUTION OF THE DISTRIBUTION OF THE RARE TERTIARY FUNCTIONS (S^4)

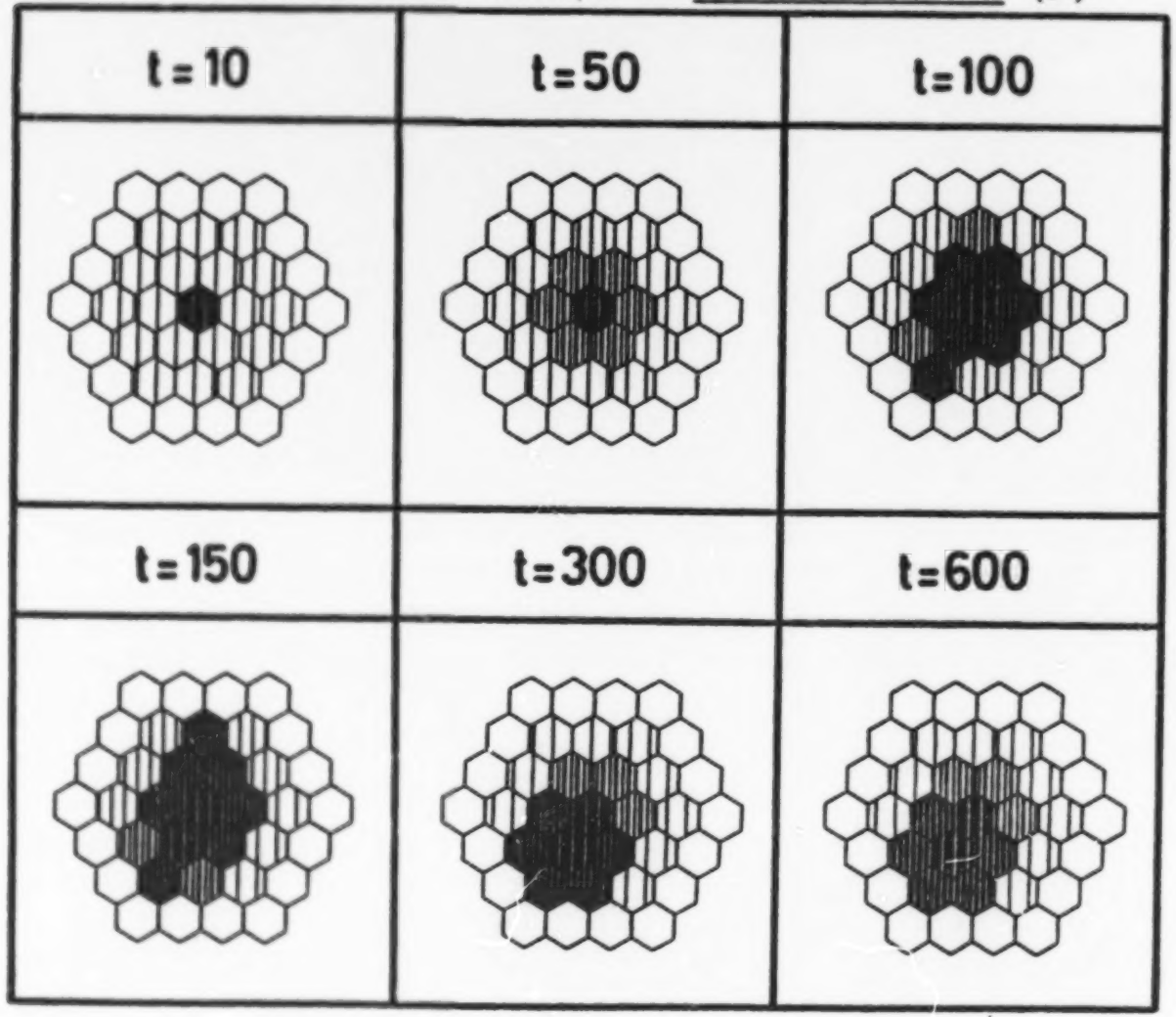

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FIGURE 3.7. EVOLUTION OF THE DISTRIBUTION OF THE BLUE-COLLAR RESIDENTS (5^6)

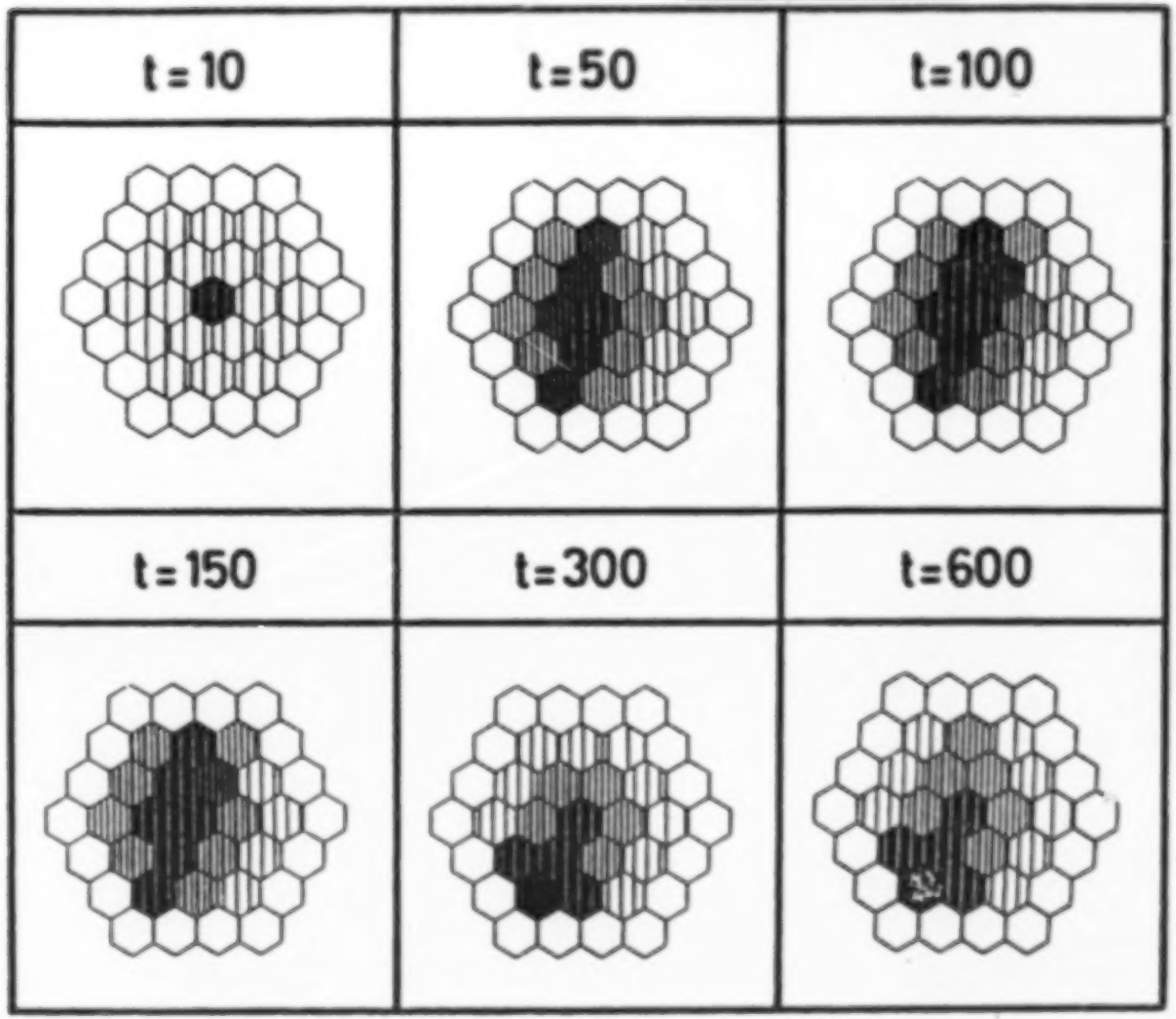

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Table 3.3. Given percentages of the two types of population working in the different economic sectors.

	Exporting industry	Exporting tertiary	Elementary loc. serv.	rare local services	Local industry
percentage of blue-collar residents working in	54	12	11	8	15
percentage of white-collar residents working in	3	32	27	28	10

White-collar workers.

In this simulation, the sources of employment for the white-collar residents are principally the exporting tertiary sector which is in the center of the city and the two types of services

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(see table 3.3). In the evolution in time of the white-collar residents (fig. 3.8) we observe that the greatest density remains in the center and as long as exporting industry is dispersed along the canal the distribution of white-collar residents is rather symmetric and circular. After the concentration of industry on point 30, the South of the city slightly attracts the white-collar residents by the development of employment in the services due to the strong increase of the density of blue-collar workers. This effect can be observed because in this simulation $\sigma^{\ell} = .0005$, which corresponds to a very small affinity between the same type of people, and $\eta^{\ell} = .0018$ which represents an indifference among the white-collar residents with regard to living near exporting industry.

On figure 3.9 we observe that the average density of population for the center and for the two hexagon rings quickly reaches (t = 100) a stationary value for the white-collar residents (S^7), although the average density of blue-collar residents is strongly influenced by the evolution of the distribution of exporting industry and reaches only a stationary value at t = 250 units.

These effects can also be observed on figure 3.10 which shows the evolution in time of the percentage of each type of population for some particular points (this figure corresponds to a simulation where exporting industry is concentrating in the

FIGURE 3.8. EVOLUTION OF THE DISTRIBUTION OF THE WHITE-COLLAR RESIDENTS (s^7)

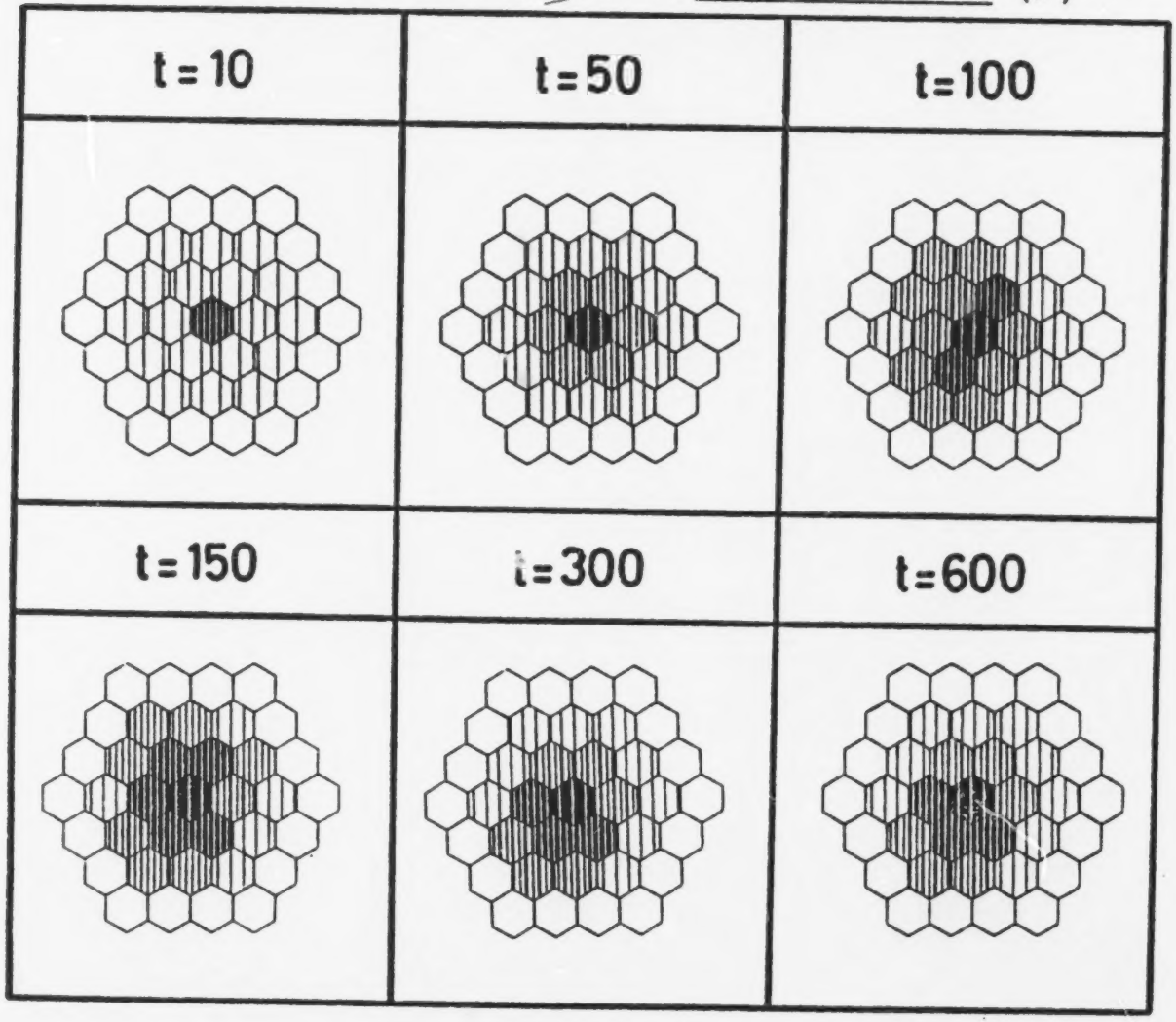

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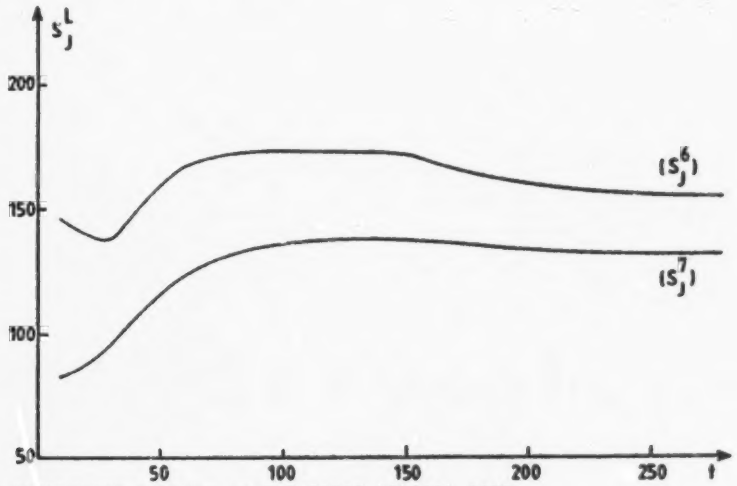
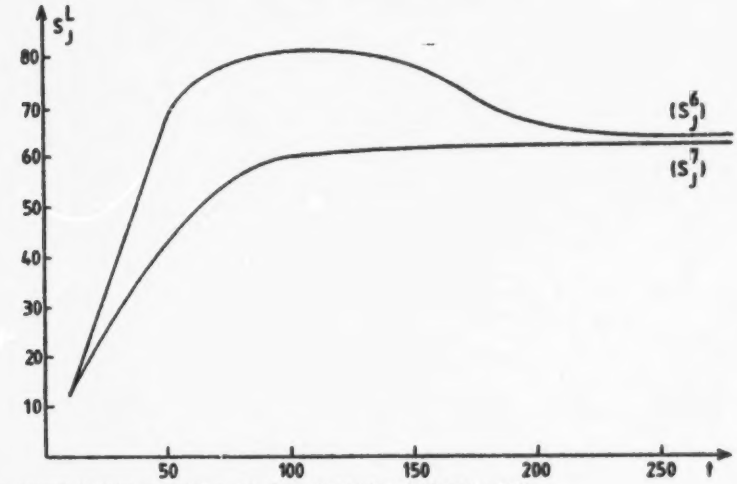
FIGURE 3.9. EVOLUTION OF POPULATION DENSITY

POPULATION DENSITY IN THE CENTER



AVERAGE POPULATION DENSITY IN THE FIRST HEXAGON RING



AVERAGE POPULATION DENSITY IN THE SECOND HEXAGON RING

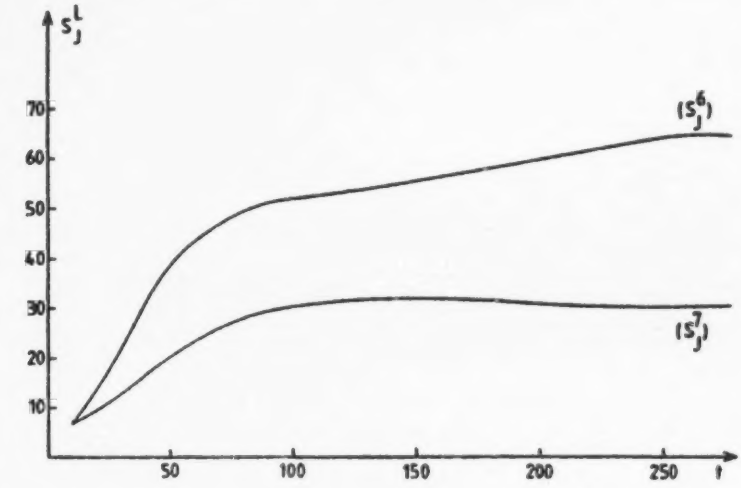


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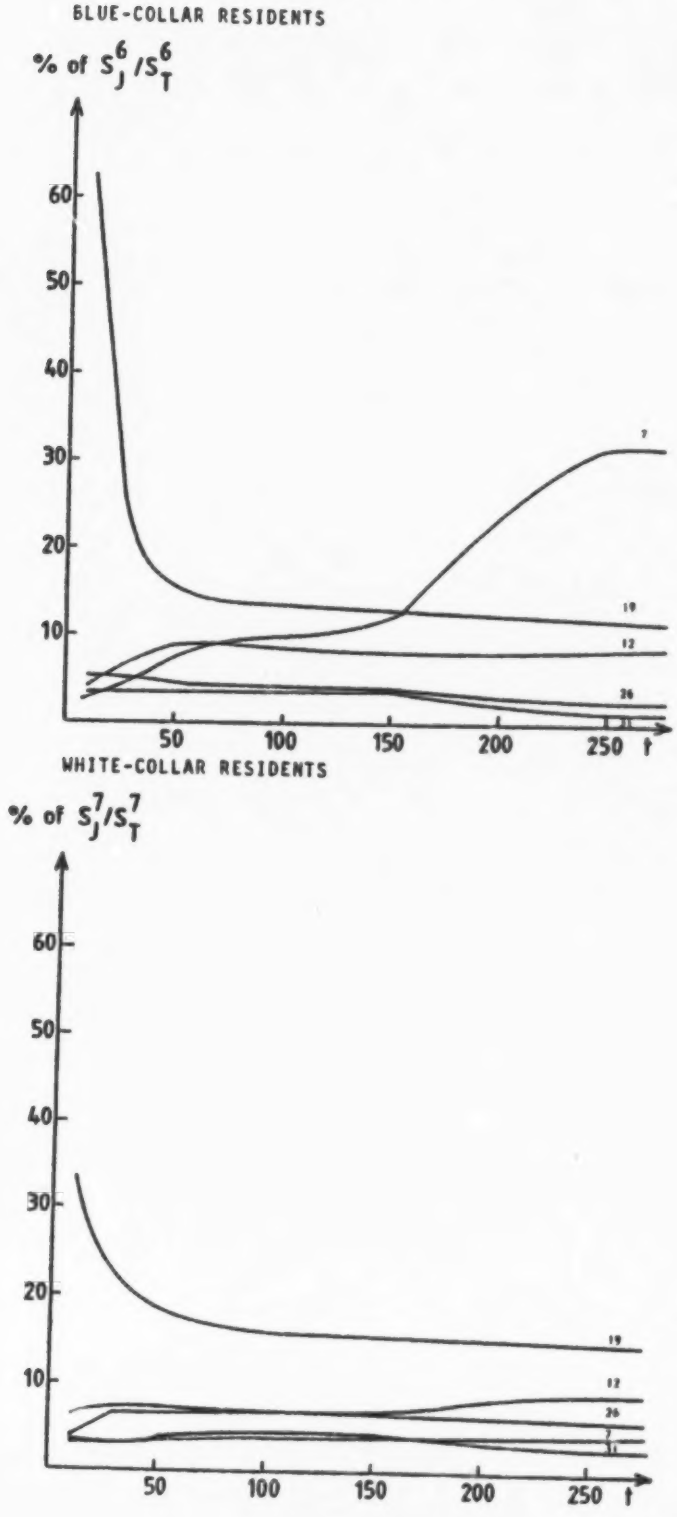
FIGURE 3.10 EVOLUTION OF RESIDENTS LIVING ON SOME PARTICULAR POINTS (7,12,19,26 and 31)



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North of the city on point 7).

Average distances and costs.

If we look at the evolution of the mean haulage distance of the local functions (fig. 3.11) we observe that, in a first phase, this global index increases very quickly, reaches its maximal value around t = 50 units and after that decreases to a value which remains constant. As far as the average commuting distance of the blue-collar residents is concerned (TM^6) (fig. 3.12), it increases first as the local functions do but after a strong decrease, it increases again. As all the variables have reached their final total value at t = 100 that means that for the same number of blue-collar residents their average commuting distance and also their average commuting cost are smaller when exporting industry is spread out along the canal than when it is centralized on a point. The evolution of the average commuting distance of the white-collar residents also presents to some extent this effect, which can correspond to the small increase of white-collar residents in the South when industry is concentrated there. The table 3.4 gives the values of the "concentration index" for each variable during the growth of the city.

FIGURE 3.11. EVOLUTION OF THE MEAN HAULAGE DISTANCE FOR THE LOCAL FUNCTIONS (S^3 ELEMENTARY TERTIARY
S^4 RARE TERTIARY
S^5 LOCAL INDUSTRY)

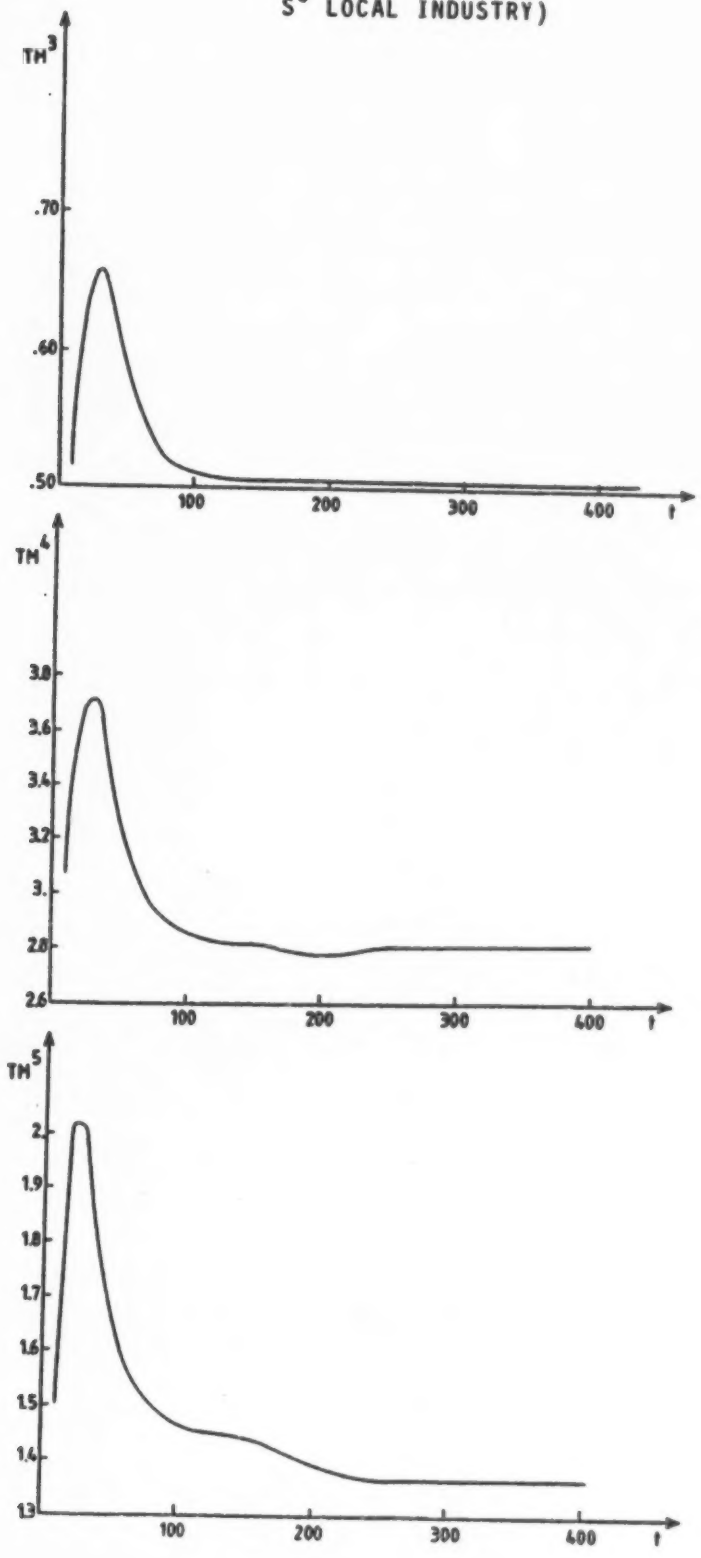

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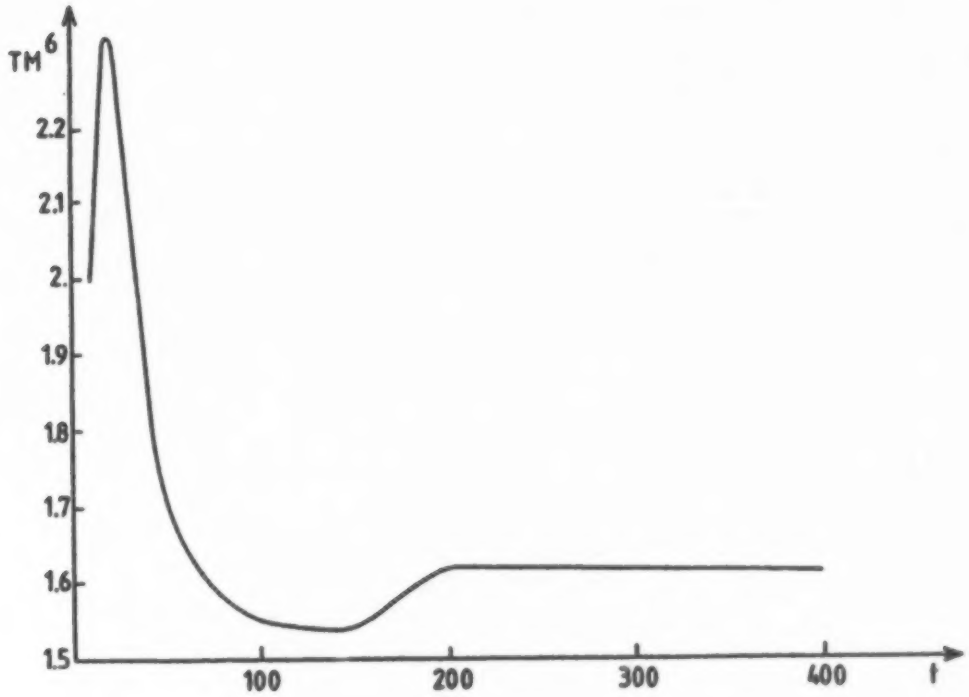
FIGURE 3.12. EVOLUTION OF THE AVERAGE COMMUTING DISTANCE FOR RESIDENTS



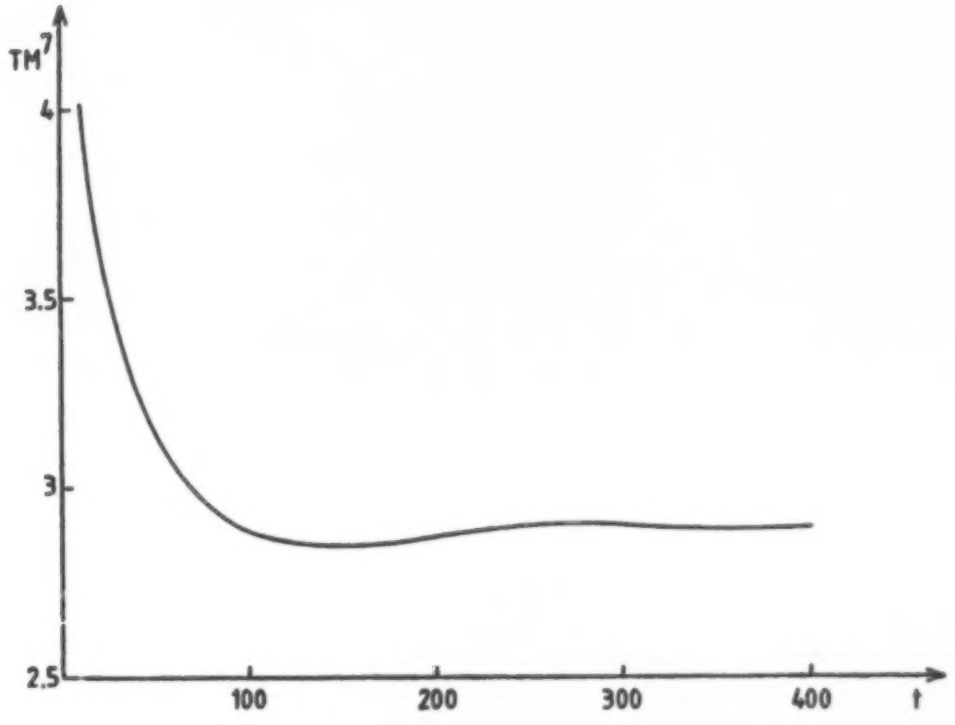


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Table 3.4. Concentration indices in time.

	TI^1	TI^2	TI^3	TI^4	TI^5	TI^6	TI^7
t = 10	7.0	116.0	20.7	20.3	15.4	55.7	30.7
t = 50	48.9	167.3	16.0	18.1	13.1	55.3	40.1
t = 100	62.0	171.8	18.9	21.5	15.9	65.0	46.9
t = 150	70.8	172.3	19.1	21.6	16.4	67.8	47.3
t = 300	226.0	172.0	30.4	20.0	44.5	171.0	45.0
t = 600	225.0	172.0	30.4	20.0	44.3	170.0	45.1

This table shows that the only indices which are not affected by the concentration of industry are those corresponding to the rare local services TI^4 and to the white-collar residents TI^7.

IV.B. Effects of changes in the internal cooperativity of exporting industry ρ^4.

In the previous reports[3], we explored the influence of three main parameters of the model on the urban structure:

- the internal cooperativity of the elementary and

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rare local services.

- the internal affinity of residents
- the transportation cost of activities and residents, taken together.

With this new version of the model, we intend to explore the influence of another important parameter - the internal cooperativity of exporting industries ϱ^1 - and analyze the influence of different attitudes of the residents of type L with respect to the total cost of travel b^L. Later on, in chapter 4, we will split the total cost of travel into real cost and time spent for the journey-to-work.

For these two last parameters (ϱ^1 and b^L), the other parameters being constant, we find critical zones where small variations of the value of one of them leads to either a structure where exporting industry is concentrated on one point or a structure where it is spread out along the transportation axis.

a) The meaning of the internal cooperativity of an economic activity.

Each economic variable we consider in the model is composed of a group of activities quite different in nature but

having two characteristics in common :

- their degree of dependence on the outside world (exporting, local)
- their dominant location criteria

This does not tell us anything about the relationships existing between the different components of the group.

The purpose of introducing the internal cooperativity parameter (ϱ^1) is precisely to try to qualify the intensity of the spatial relationships existing between the activities of the group. When the internal cooperativity is high, it means not only that the functional relationships are intense, but also that the components of the group need to be located close to each other. When the internal cooperativity is low it may mean several things :

- the activities have strong links with each other but no need of spatial proximity. For instance, the generalized use of computer devices have largely contributed to decrease the internal cooperativity of activities strongly linked by the need of information.
- the activities are weakly linked to each other.

Thus we see that this parameter covers a complex entirety of economic characteristics. The modification of its value may express evolutions very different in nature.

In the case of exporting industrial activities, the internal cooperativity is directly related to the industry mix, that happend to locate in the city either by chance or by induction from the outside world on a specific site of regional importance. It can vary widely because fluctuations are very important in this case.

b) Increasing the internal cooperativity of exporting industries leads to a bifurcation point.

For $\rho^1 \leq .001625$ we obtain an urban structure where exporting industry is spread out along the communication axis.

For $\rho^1 > .001627$ the urban structure is characterised by an exporting industry which is concentrated on a point of the communication axis.

For a value of ρ^1 near this bifurcation point for example $\rho^1 = .00165$, exporting industry is always concentrated on point 7 in the North of the lattice for any small fluctuations of the initial value of the variables. But for $\rho^1 \geq .0017$ the place where industry concentrates is determined by the particular initial conditions.

Finally when ϱ^4 becomes equal or greater than .0025 exporting industry stays in the center of the city where the greatest number is launched in the beginning of the simulation.

These results are summarized in figure 3.13 which presents the distribution of exporting industry, at the stationary state, for different values of the parameter Note that the final structure obtained with $\varrho^4 = .0016$ is similar to the structure which occurred temporarily during the simulation with $\varrho^4 = .0017$ at t = 150 units.

c) The influence of this bifurcation point on the rest of the city.

By changing the internal cooperativity of exporting industry we modify completely the distribution of the other variables.

As we have seen in the previous paragraphs, the location of the local industry is strongly affected by the distribution of exporting industry (Figure 3.14 and table 3.6).

FIGURE 3.13. DISTRIBUTION OF EXPORTING INDUSTRY FOR DIFFERENT VALUES OF THE INTERNAL COOPERATIVITY (OF EXPORTING INDUSTRY) ϵ^1

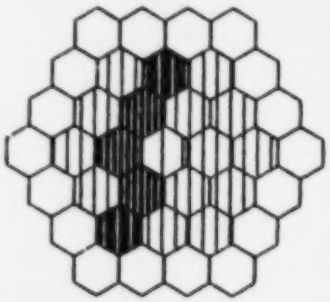
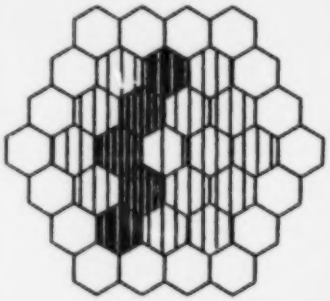
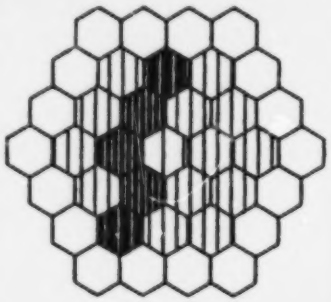
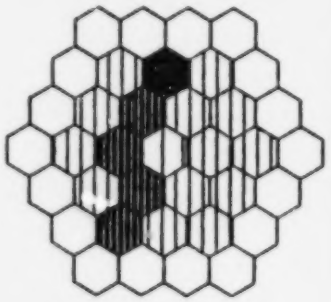
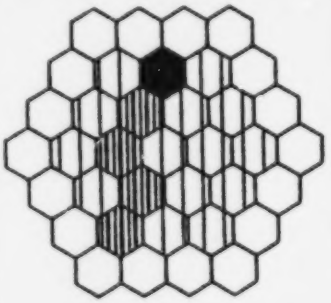
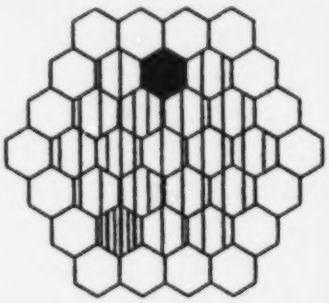
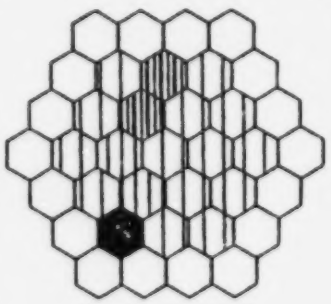
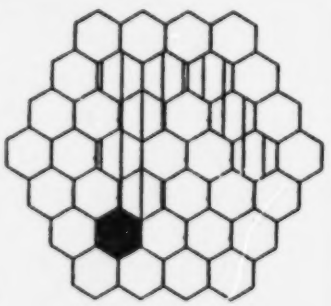
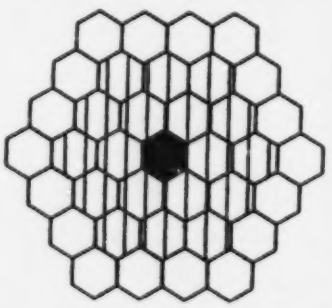
$R0^1$=.0015	$R0^1$=.0016	$R0^1$=.001625
		
$R0^1$=.001627	$R0^1$=.00163	$R0^1$=.0017
		
$R0^1$=.0017	$R0^1$=.0022	$R0^1$=.0025
		

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FIGURE 3.14. DISTRIBUTION OF LOCAL INDUSTRY FOR DIFFERENT VALUES OF THE INTERNAL COOPERATIVITY

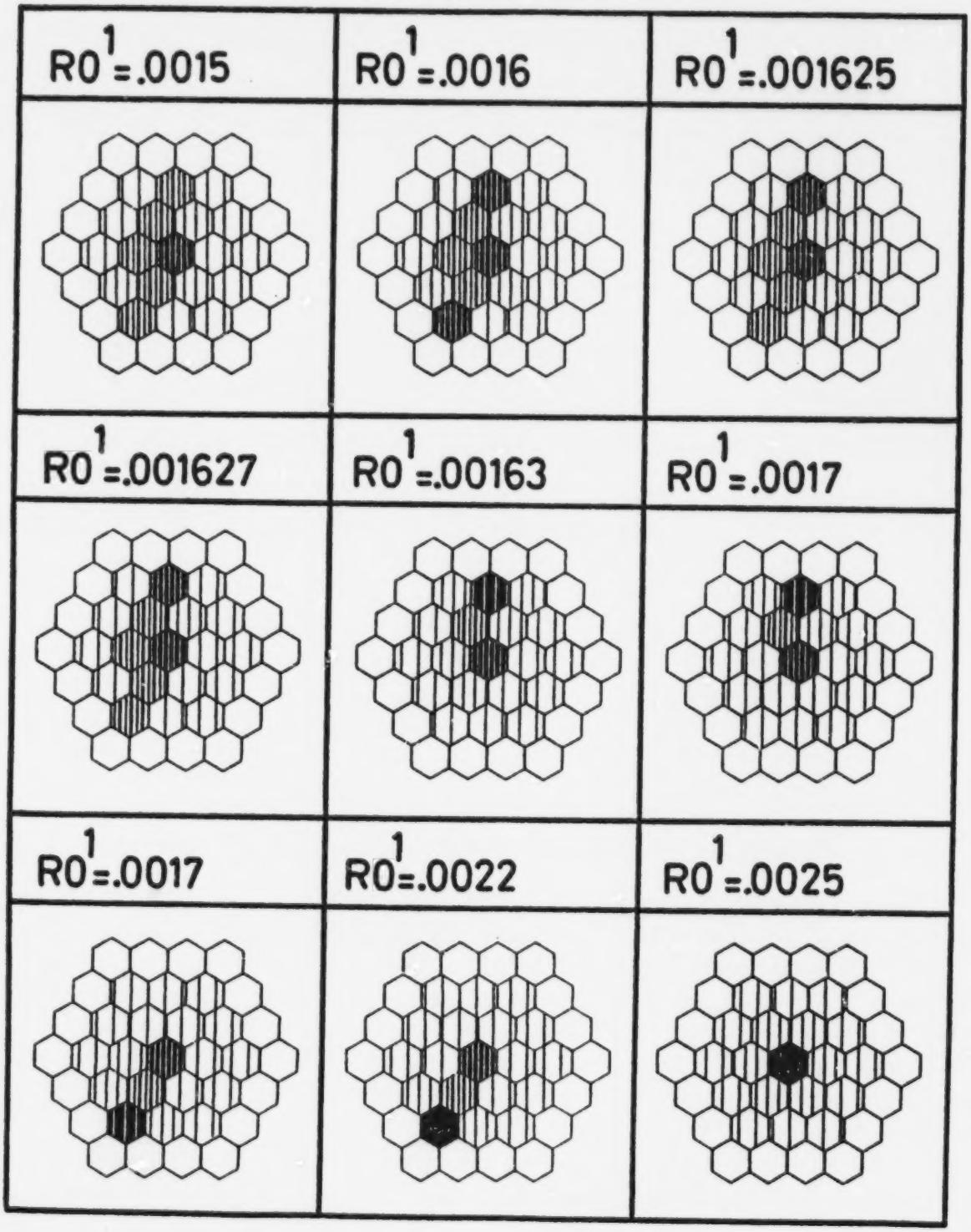

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Table 3.4. Percentage of employment in the local industry sector for some particular points, in function of ρ^1. (N = North, S = South)

ρ^1	% of S^5_{center}	% of S^5_7	% of S^5_{30}
: .0012	16.8	7.6	7.8
: .0015	17.4	8.7	8.9
: .001625	17.0	12.0	8.7
: .001627	16.7	15.8	7.4
: .00163(N)	14.3	36.9	2.7
: .0017 (N)	13.8	41.1	2.0
: .0017 (S)	13.6	2.3	41.9
: .0018 (S)	13.1	1.7	46.0
: .002 (S)	12.6	1.2	49.8
: .0022 (S)	12.4	1.0	51.6
: .0025	67.0	1.6	1.3

On this table we note the decrease of the percentage of local industry concentrated in the center conjointly with the concentration of this employment on the point where exporting industry is concentrated. But of course for $\rho^1 = .0025$ when exporting industry stays in the center, we have 67% of

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employment in local industry sector in the center also.

The distribution of the local services (figures 3.15 and 3.16) are also strongly affected by the variation of the parameter ϱ^1 , as the residential location of the inhabitants is also strongly influenced by this parameter (figures 3.17 and 3.18).

Looking at the "concentration index" TI for these different variables (fig. 3.19), the strong concentration of exporting industry and of the blue-collar residents appears very clearly. We observe also an interesting evolution in the curve of the concentration index for the local industry. However, although the distribution of the services and the white-collar residents is modified, their concentration index remains rather constant for increasing values of

The distribution of the total employment (figure 3.20) shows that, for low internal cooperativity of exporting industry (ϱ^1 = .0015), 28% of the total employment is in the center and 40% is distributed along the canal. For the transition value of ϱ^1 : .001627 we have 27.5% in the center and 42.5% along the communication axis. When industry is concentrated on a point (for example ϱ^1 : .0017) this point has 37% of the total employment and the center has only 26.8%. And

FIGURE 3.15. DISTRIBUTION OF ELEMENTARY LOCAL TERTIARY FUNCTIONS FOR DIFFERENT VALUES OF THE INTERNAL COOPERATIVITY

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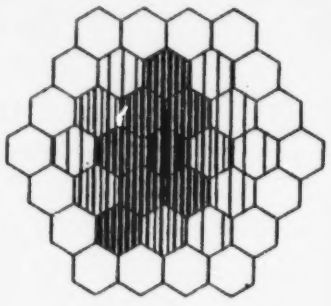
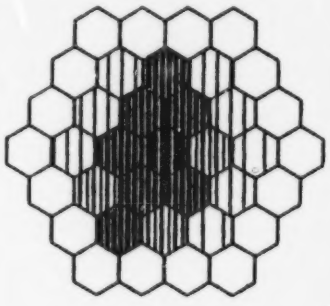
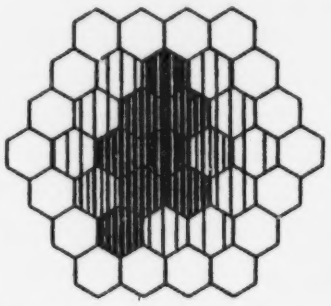
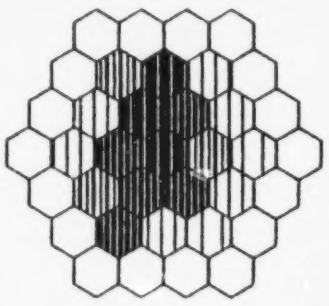
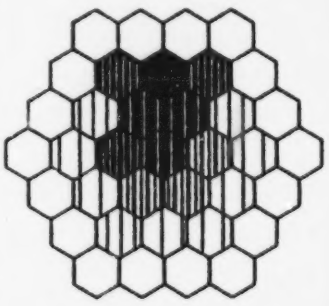
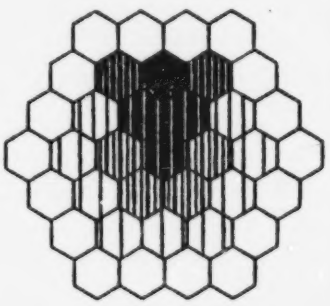
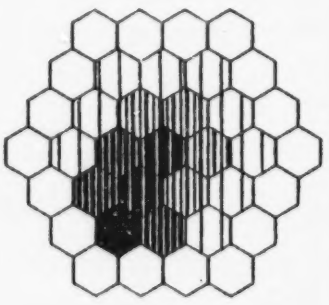
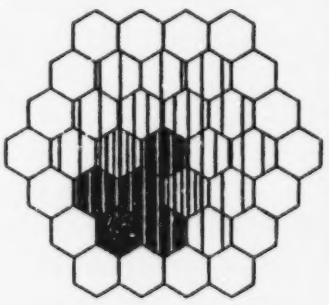
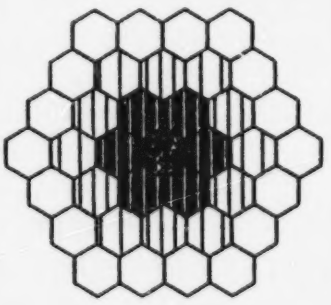
		
$R0^{1}=.001627$	$R0^{1}=.00163$	$R0^{1}=.0017$
		
$R0^{1}=.0017$	$R0^{1}=.0022$	$R0^{1}=.0025$
		

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FIGURE 3.16. DISTRIBUTION OF RARE LOCAL TERTIARY FUNCTIONS FOR DIFFERENT VALUES OF THE INTERNAL COOPERATIVITY

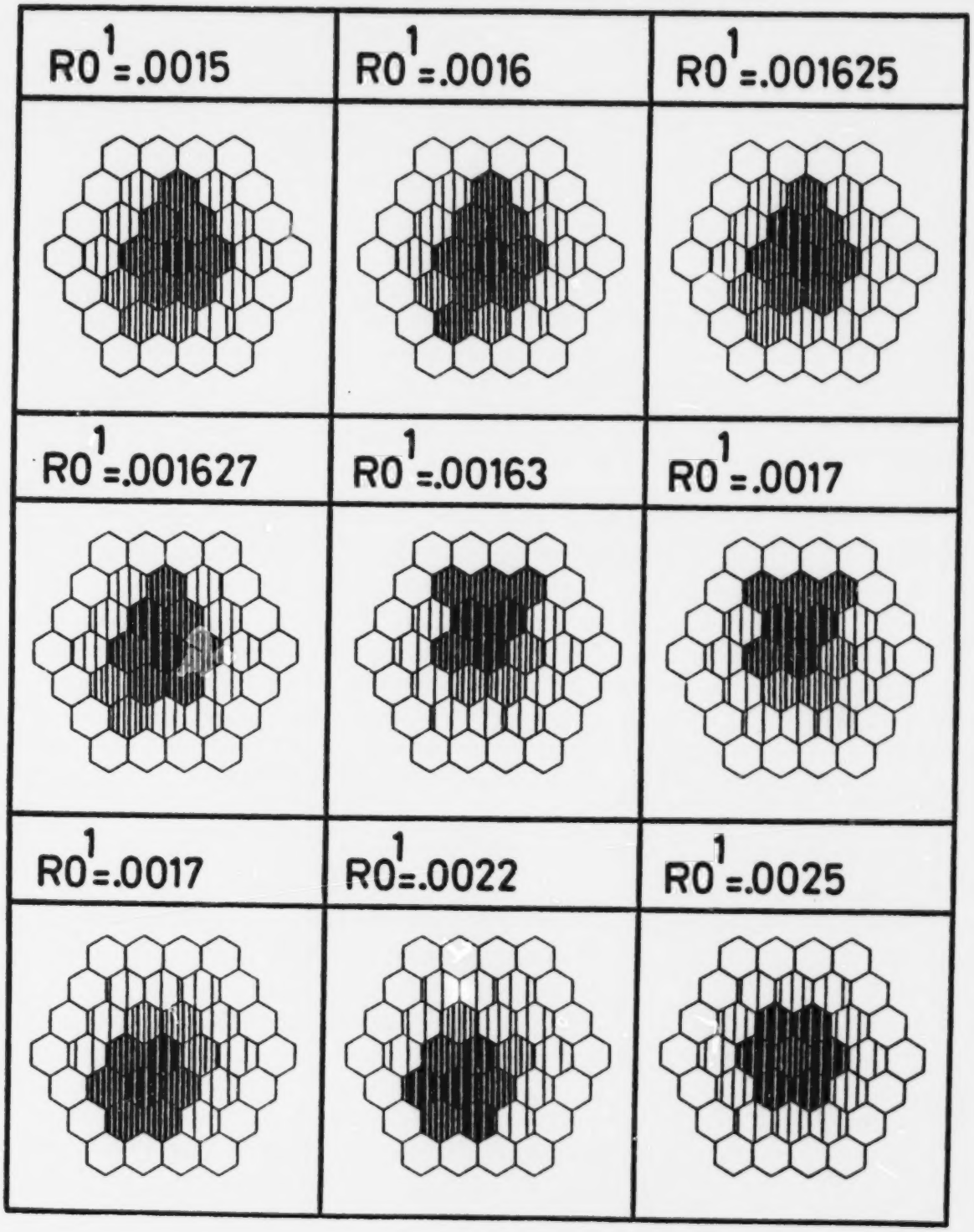

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FIGURE 3.17. DISTRIBUTION OF BLUE-COLLAR RESIDENTS FOR DIFFERENT VALUES OF THE INTERNAL COOPERATIVITY

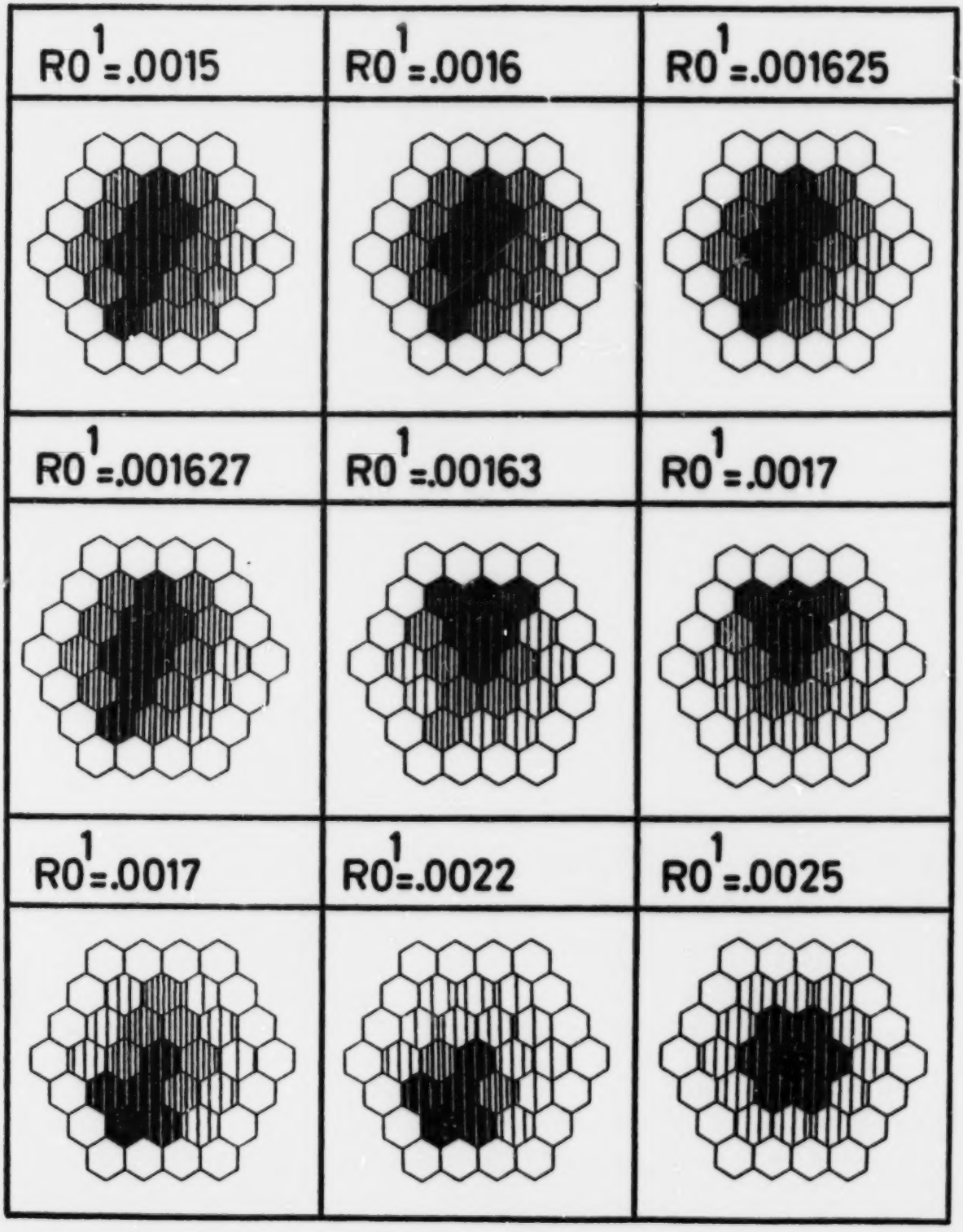

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FIGURE 3.18. DISTRIBUTION OF WHITE-COLLAR RESIDENTS FOR DIFFERENT VALUES OF THE INTERNAL COOPERATIVITY

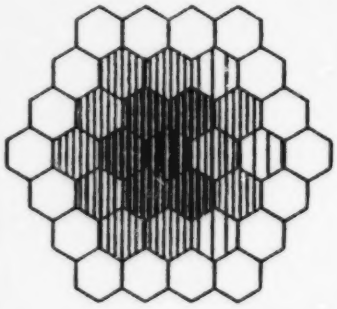
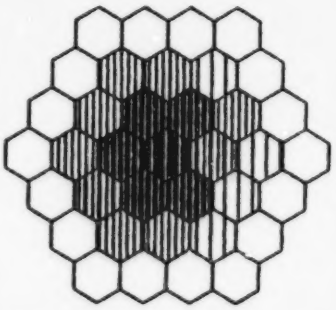
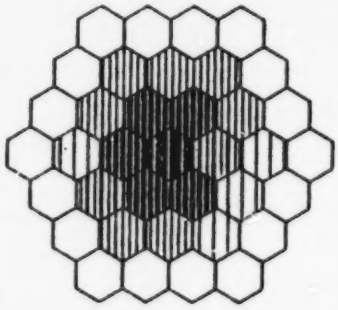
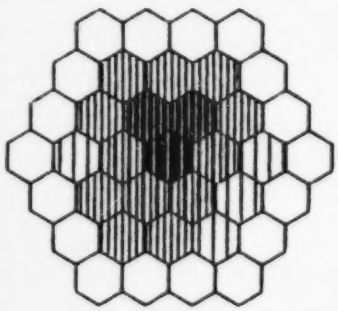
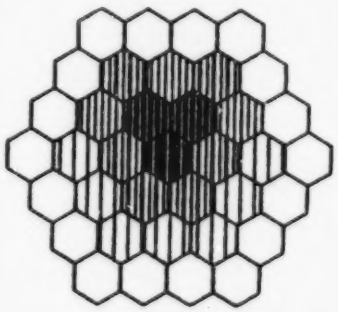
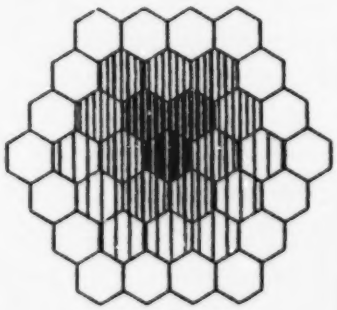
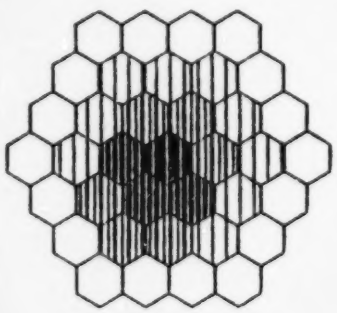
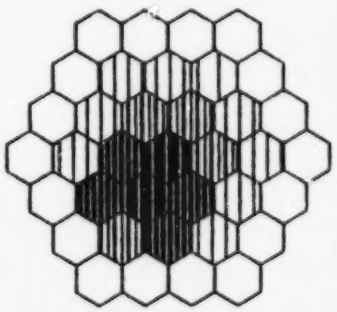
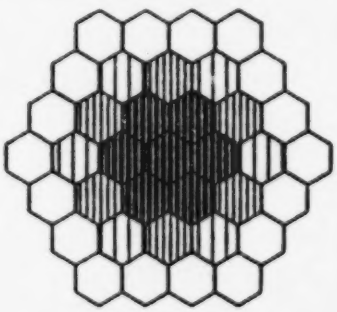
$R0^1=.0015$	$R0^1=.0016$	$R0^1=.001625$
		
$R0^1=.001627$	$R0^1=.00163$	$R0^1=.0017$
		
$R0^1=.0017$	$R0^1=.0022$	$R0^1=.0025$
		

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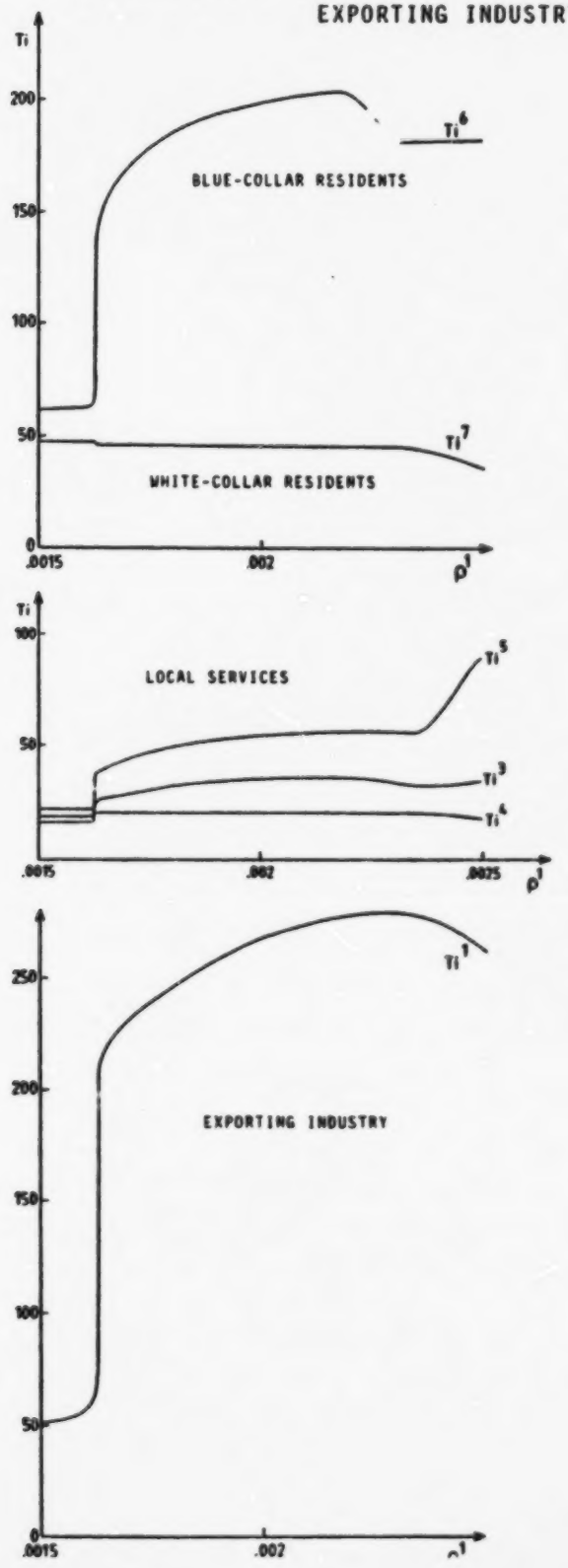
FIGURE 3.19. CONCENTRATION INDEXES FOR RESIDENTS AND JOBS IN FUNCTION OF THE INTERNAL COOPERATIVITY OF EXPORTING INDUSTRY (ρ^{-1})



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for larger ρ^1 : .0022 the point where exporting industry remains has 44.9% and the center 26.5%. So the percentage of the total employment in the center is not greatly modified by changing ρ^1 . But it is the distribution of the employment along the communication axis which is deeply affected.

Also if we look at the distribution of the total population (figure 3.21), by increasing ρ^1 we have a structure with two residential poles and the complete modification of the symmetry of the city.

IV.C. Influence of different attitudes of people towards the global cost of travel (b^L).

a) The importance accorded by people to the cost of travel.

The global attitude of a person towards his journey-to-work covers a complex entirety of reactions that we need to synthesize. In terms of "cost", for someone the time will be important, for another it will be the real cost. In the following simulations, we have not separated the two notions since we do not have any transportation system on the theoretical lattice yet. We will be able to do so in chapter 4.

The global cost we consider here is seen in a subjective

FIGURE 3.20. DISTRIBUTION OF TOTAL EMPLOYMENT FOR DIFFERENT VALUES OF THE INTERNAL COOPERATIVITY

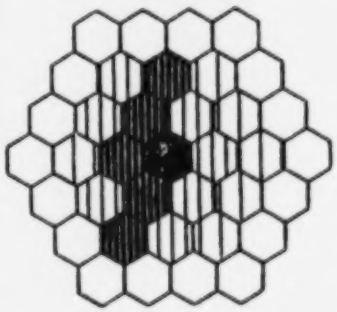
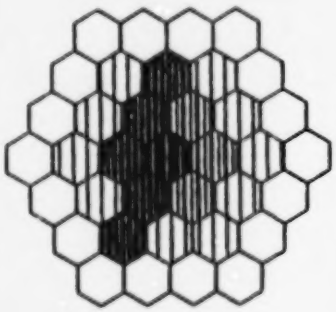
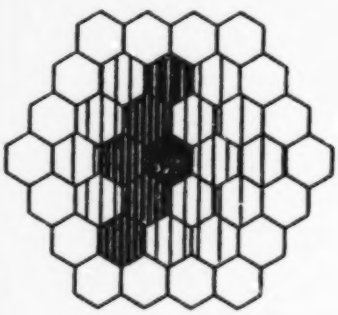
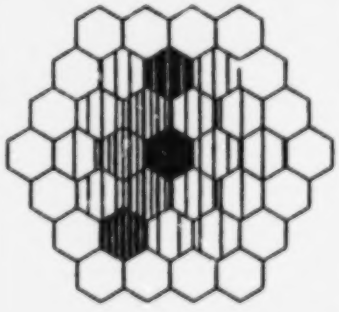
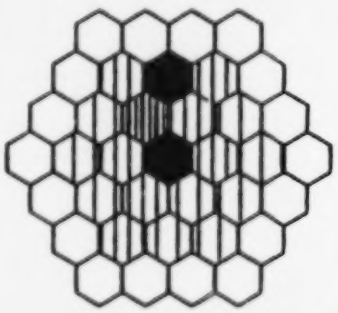
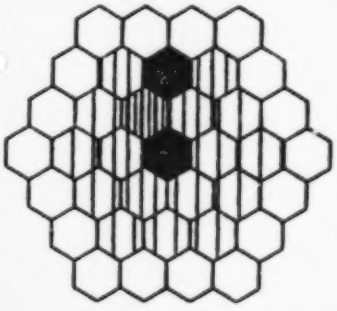
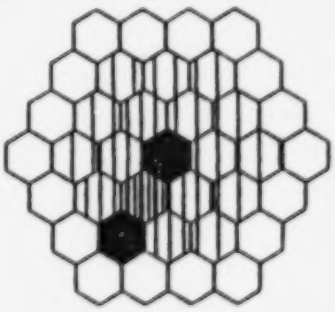
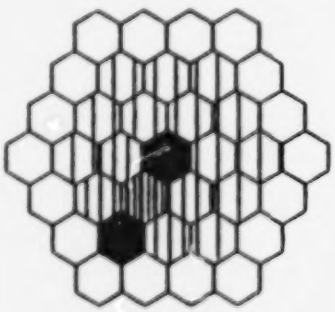
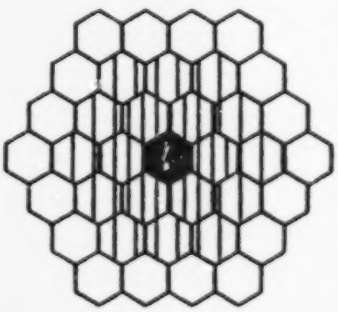
$R0^1 = .0015$	$R0^1 = .0016$	$R0^1 = .001625$
		
$R0^1 = .001627$	$R0^1 = .00163$	$R0^1 = .0017$
		
$R0^1 = .0017$	$R0^1 = .0022$	$R0^1 = .0025$
		

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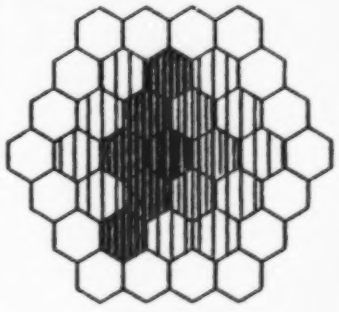
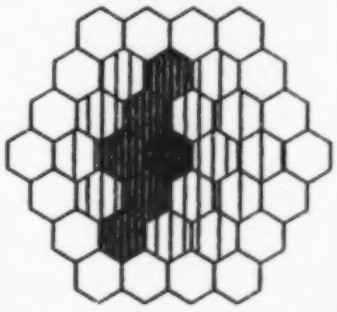
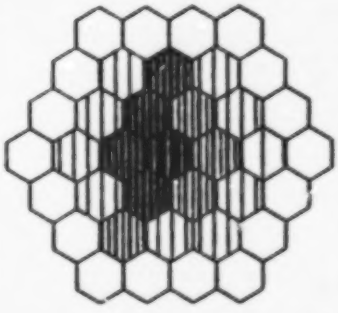
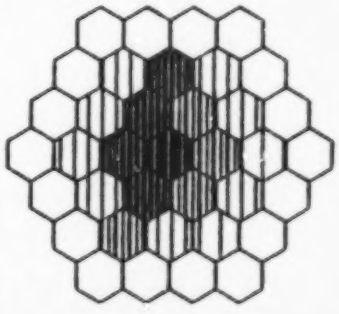
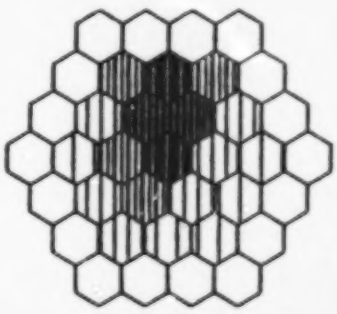
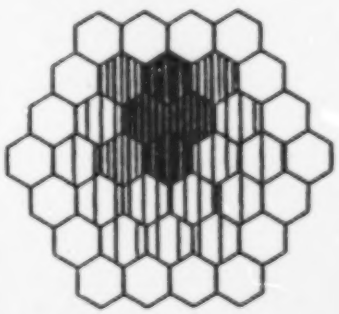
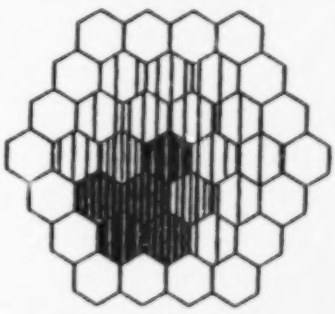
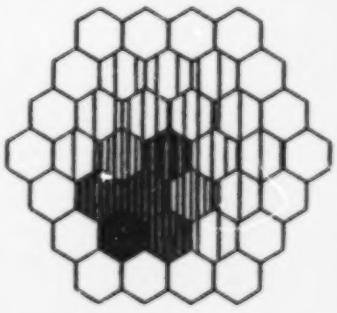
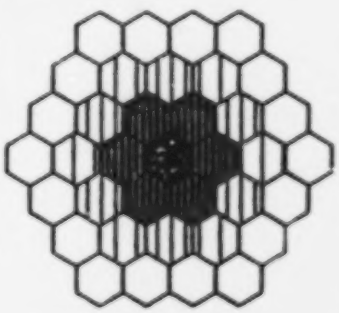
FIGURE 3.21. DISTRIBUTION OF TOTAL POPULATION FOR DIFFERENT VALUES OF THE INTERNAL COOPERATIVITY

$R0^1 = .0015$	$R0^1 = .0016$	$R0^1 = .001625$
		
$R0^1 = .001627$	$R0^1 = .00163$	$R0^1 = .0017$
		
$R0^1 = .0017$	$R0^1 = .0022$	$R0^1 = .0025$
		

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manner : it is the importance accorded to it by each type of resident not only as a function of his income but also as a function of his cultural value system.

Practically, when we say that the importance accorded to the global cost of travel increases, it means that the freedom of action of the resident decreases, or that his travel circle narrows.

b) The unexpected influence of people's attitudes on the location of exporting industry.

For a given value of ϱ^1 (the internal cooperativity of exporting industry), by increasing the value of the parameter b^L; (L being the type of residents), we pass from an urban structure where exporting industry is concentrated on a point to an urban structure where exporting industry is spread out along the communication axis. So there is an obvious influence of people's attitudes towards transportation on the location of economic activities, even in the case of exporting industries which are often very large firms having quite strong and specific spatial requirements and no economic link with the local population.

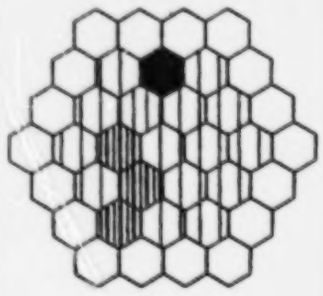
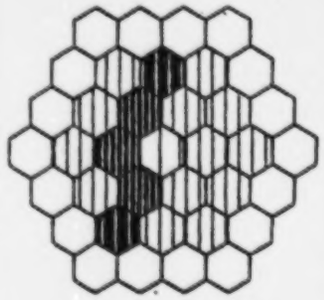
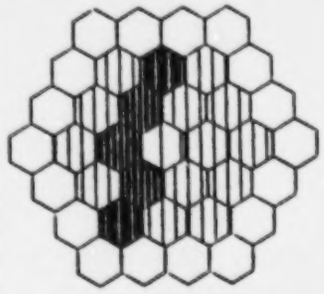
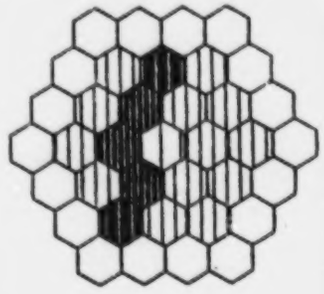
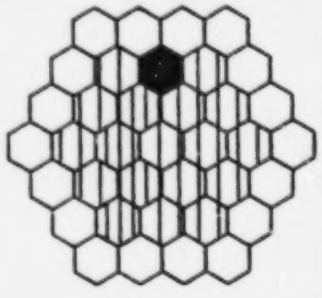
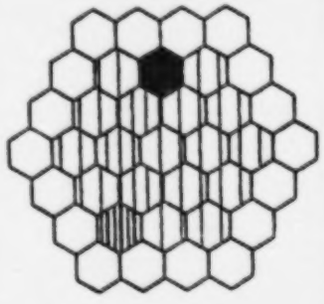
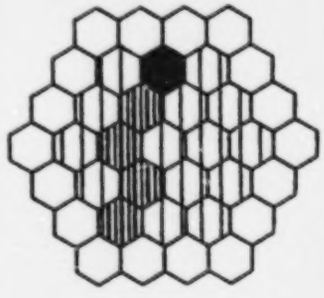
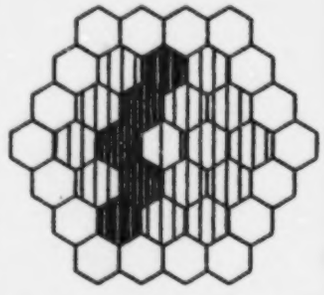
Furthermore, from figure 3.22, we see that this bifur-

cation point changes when the internal cooperativity of exporting industry increases. So there is a fight between the strong internal links that keep activities together and the attitudes of people that force them to spread out along the transportation axis.

What are the fundamental mechanisms of this bifurcation?

When the importance of travel costs increases for the residents, this contributes to limit their spatial freedom and they tend to concentrate around the spatial structure of activities existing at that moment. So their density increases, as well as the density of all the economic activities they induce. This complex mass effect increases the price of land on many points of the lattice where exporting industries are located. These latter are quite sensitive to the price of land because they require a great deal of space for the production of their goods. Indeed the cost of land is an important item in the structure of their own production costs. So the attractivity of the point decreases for them and they will tend to locate or relocate on other points where the location advantages are the same but land is cheaper.
But they also need to be close to the other exporting industries. So if their internal cooperativity ϱ^4 is low, they

FIGURE 3.22. DISTRIBUTION OF EXPORTING INDUSTRY FOR CHANGING PERCEPTIONS OF TRANSPORTATION COSTS (BY THE BLUE-COLLAR b^1 AND WHITE-COLLAR b^2 RESIDENTS)

	$b^1=.7$ $b^2=.3$	$b^1=.9$ $b^2=.5$	$b^1=1.1$ $b^2=.7$	$b^1=1.3$ $b^2=.9$
$RO^1=.0016$				
$RO^1=.0017$				

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will relocate easily for small increases of land prices. If their internal cooperativity is high, they will start relocation at much higher densities - i.e. at much higher values of the parameter b, expressing the attitude of people towards transportation costs.

This is a very good example of all the unexpected indirect changes that can happen in a city when one modifies the cost of travel.

Let us see now in detail all the modifications that occur in the urban structure when b changes.

c) the influence of people's attitudes on the location of other components of the city.

As we can see on the following figures (figures 3.23, 3.24, 3.25) increasing the importance accorded by the population to their transportation cost influences strongly the distribution of the local functions. On figure 3.26a, we note that the percentage of this local employment in the center against the total for the city increases from 10% to 18% by increasing the values of b^1 from .7 to 1.3 and b^2 from .3 to .9.

FIGURE 3.23. DISTRIBUTION OF LOCAL INDUSTRY FOR CHANGING PERCEPTIONS OF THE TRANSPORTATION COSTS

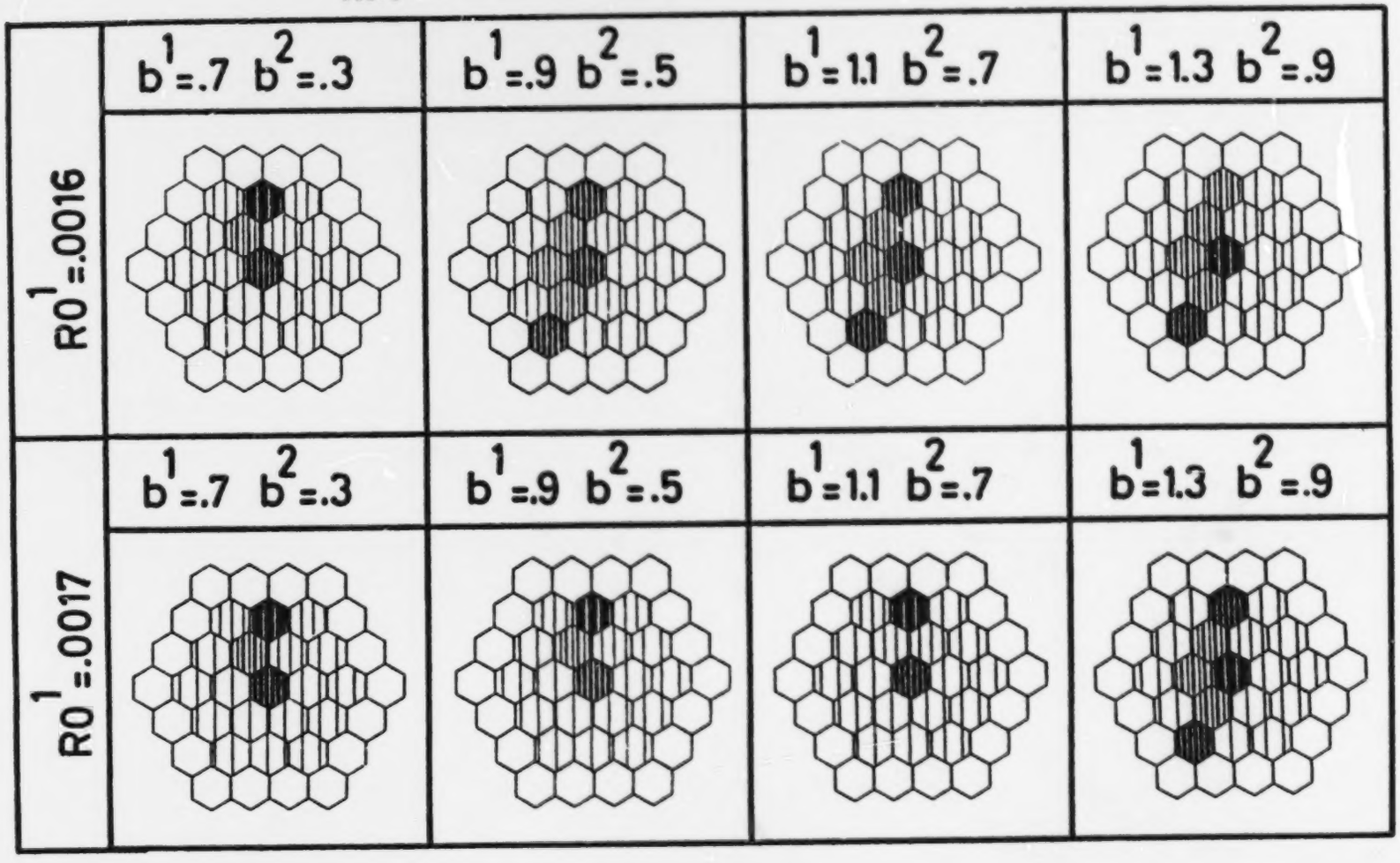

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FIGURE 3.24. DISTRIBUTION OF ELEMENTARY LOCAL TERTIARY FUNCTIONS FOR CHANGING PERCEPTIONS OF THE TRANSPORTATION COSTS

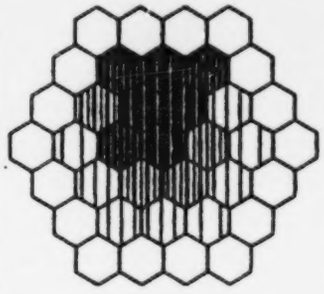
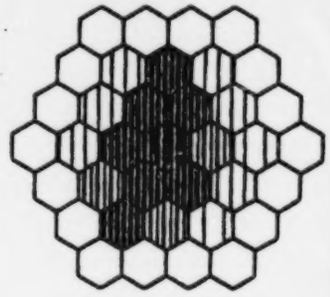
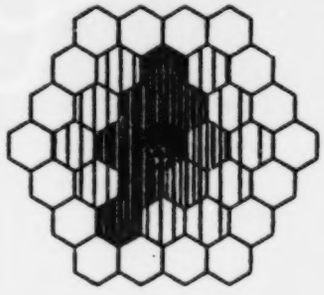
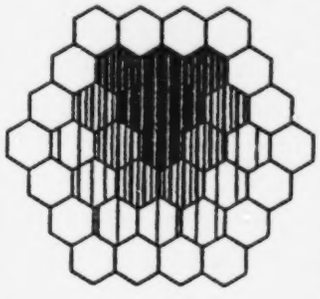
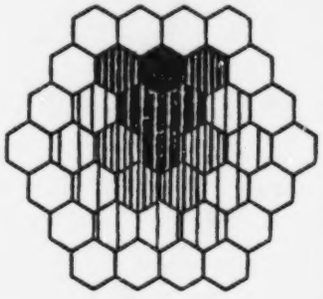
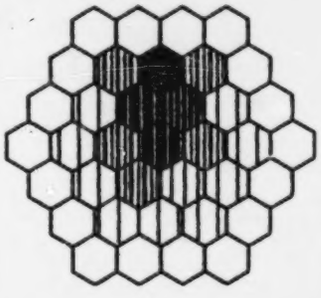
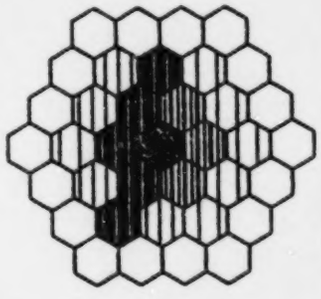
	$b^1=.7\ b^2=.3$	$b^1=.9\ b^2=.5$	$b^1=1.1\ b^2=.7$	$b^1=1.3\ b^2=.9$
$RO^1=.0016$				
$RO^1=.0017$				

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FIGURE 3.25. DISTRIBUTION OF RARE LOCAL TERTIARY FUNCTIONS FOR CHANGING PERCEPTIONS OF THE TRANSPORTATION COSTS

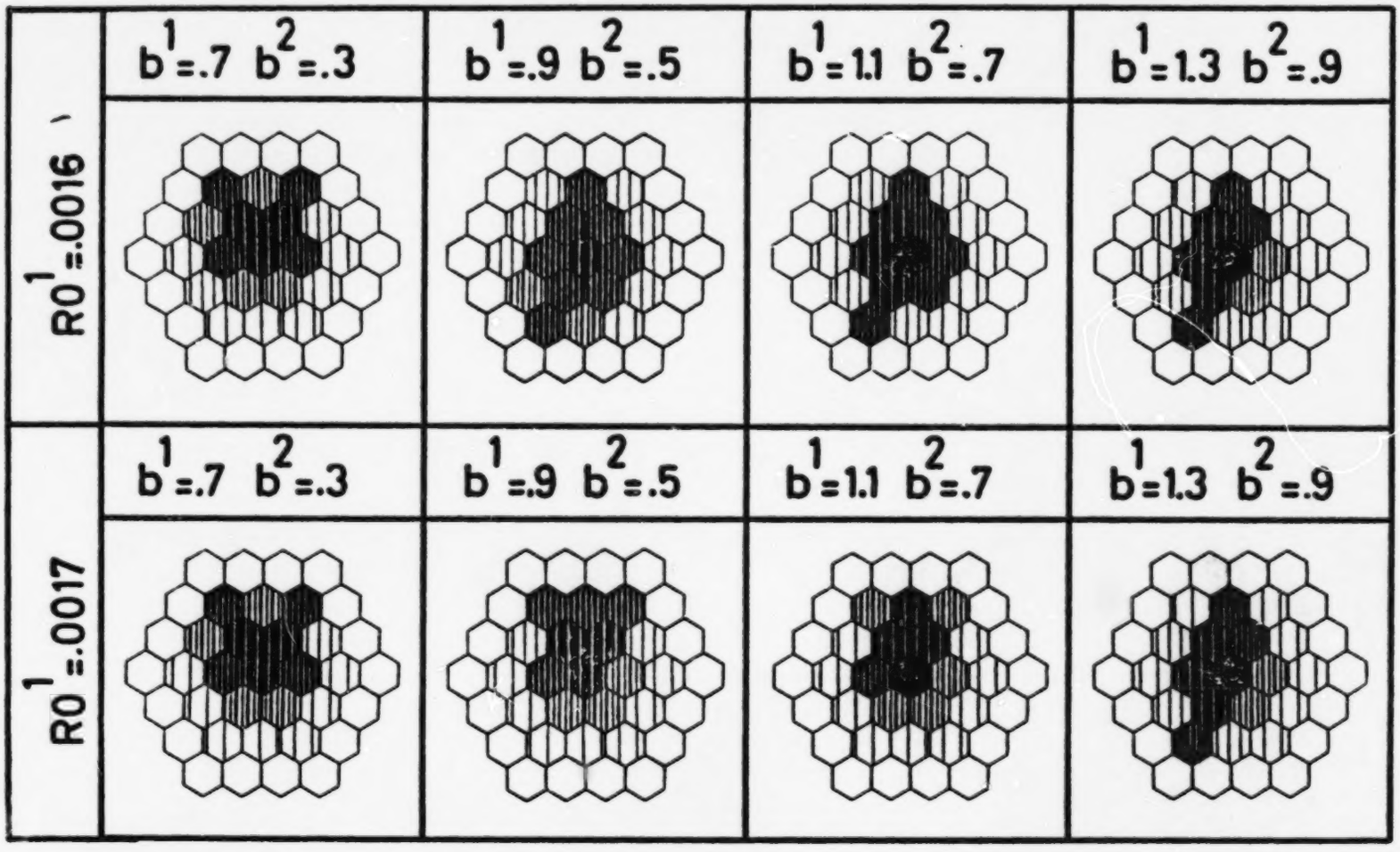

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FIGURE 3.26a. PROPORTION OF JOBS IN LOCAL FUNCTIONS LOCATED IN THE CENTER IN FUNCTION OF THE PERCEPTION OF THE TRANSPORTATION COSTS (b^l)

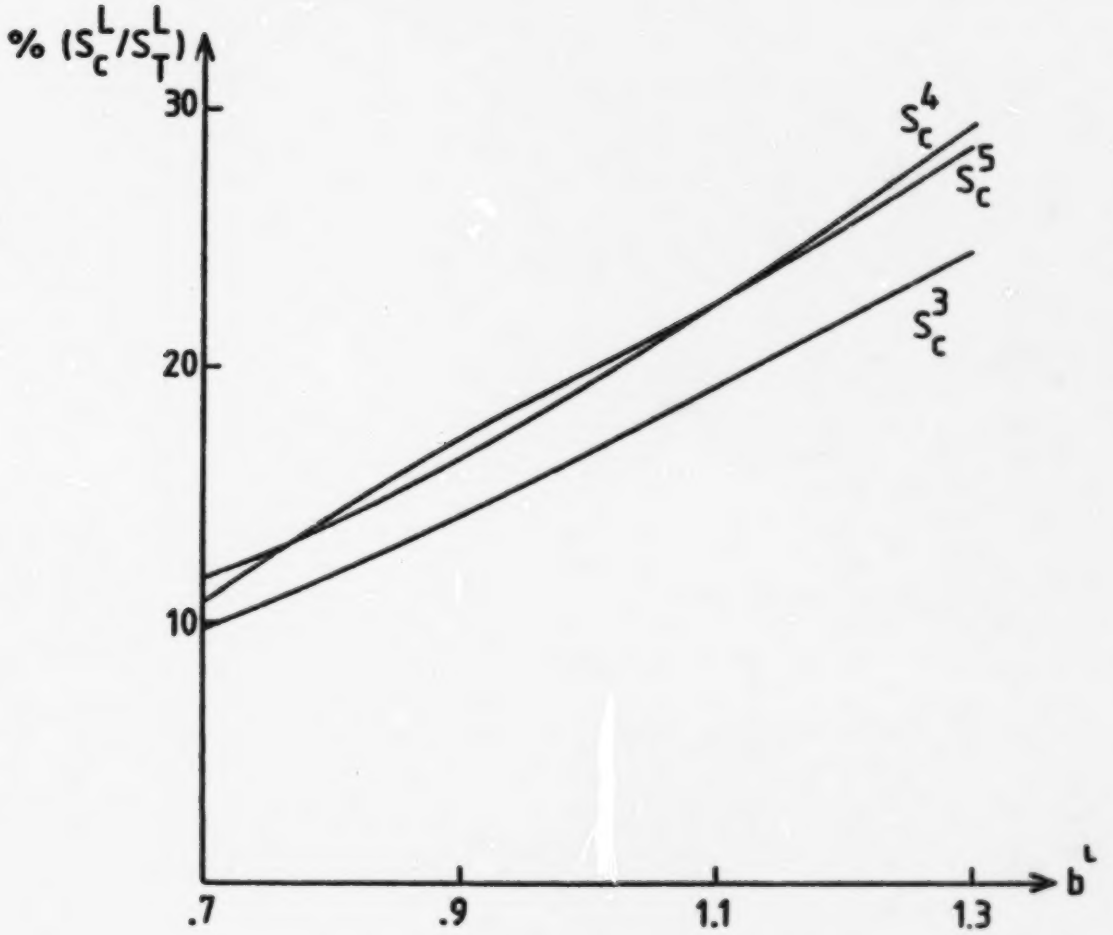

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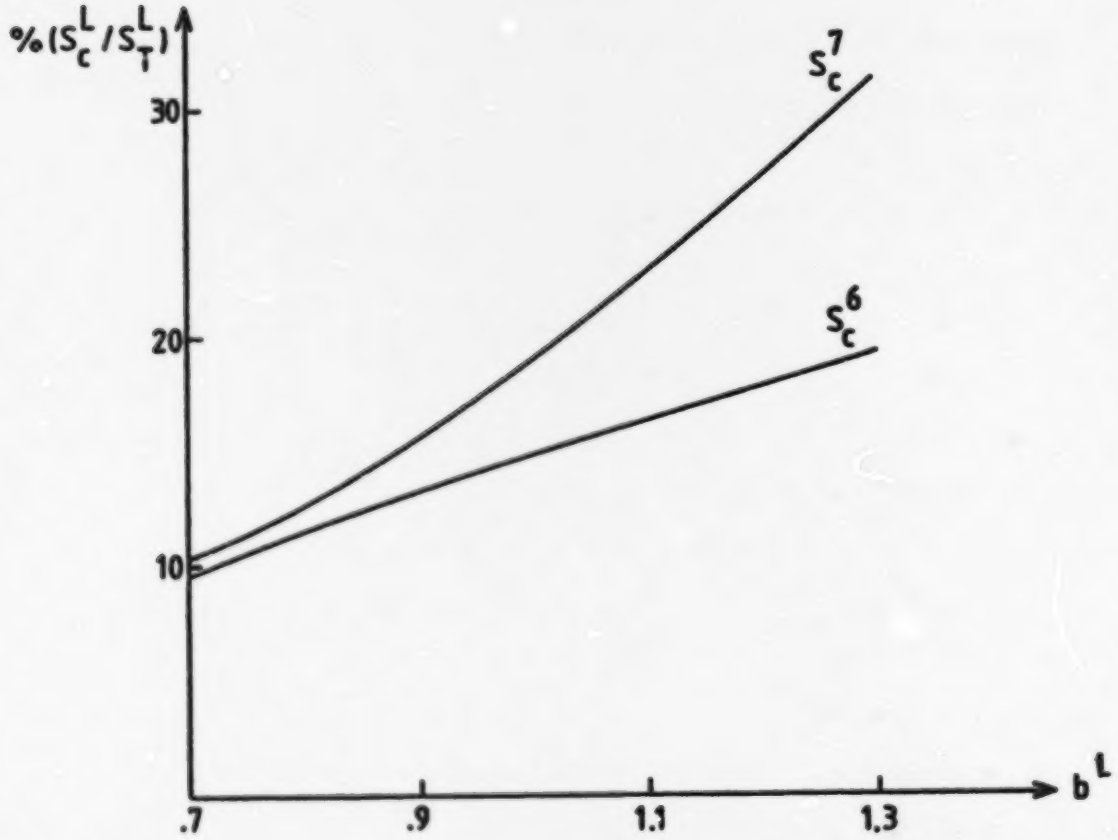
FIGURE 3.26b. PROPORTION OF RESIDENTS LIVING IN THE CENTER IN FUNCTION OF THE PERCEPTION OF THE TRANSPORTATION COSTS (b^L)



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Of course modification of the parameter b^L does affect strongly the distribution of the population (figures 3.27, and 3.28).

Augmenting the parameter b^L, increases the density of blue-collar residents at points where blue-collar jobs are concentrated, for example, in the center of the city and on the points where exporting industry is localized. On the other points, the density of blue-collar residents decreases with the increase of b^L.

As far as the white-collar residents are concerned, by increasing b^L, one increases strongly their density in the center of the city and decreases it slightly on the other points.

On figure 3.26b, we see that the percentage of white-collar residents in the center increases much more than that of the blue-collar residents. A high value of the parameter b^L encourages the gentrification of the center of the city.

Figure 3.29, 3.30 and 3.31 give the pattern of total employment, total population and total density of jobs and people for the different values of b^L. But the growth of employment and population in the center of the city, when transportation costs increase, appears more clearly on table 3.5.

FIGURE 3.27. DISTRIBUTION OF BLUE-COLLAR RESIDENTS FOR CHANGING PERCEPTIONS OF THE TRANSPORTATION COSTS

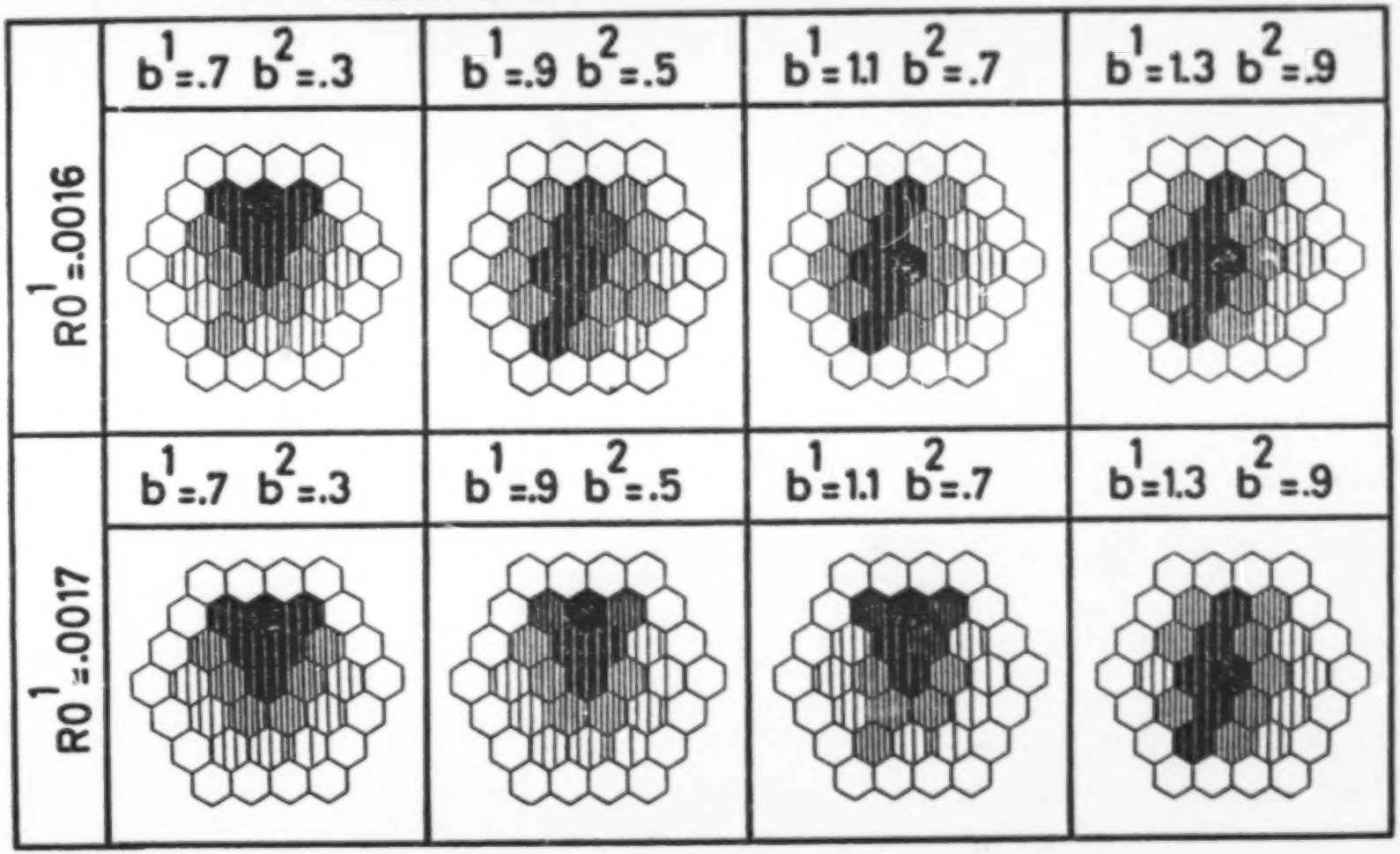

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FIGURE 3.28. DISTRIBUTION OF WHITE-COLLAR RESIDENTS FOR CHANGING PERCEPTIONS OF THE TRANSPORTATION COSTS

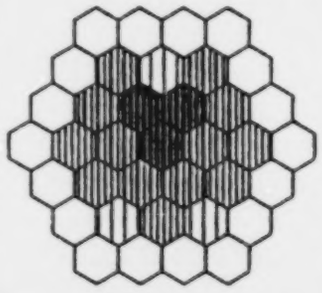
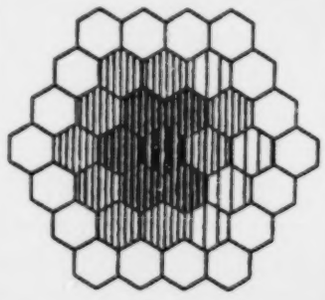
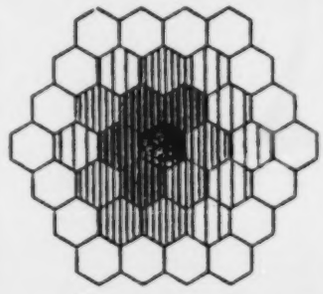
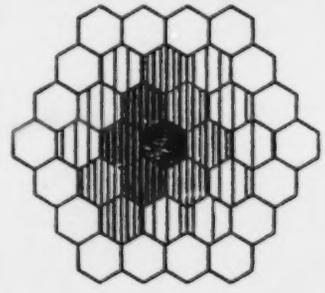
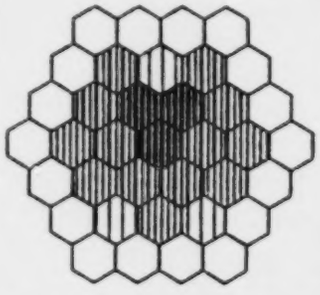
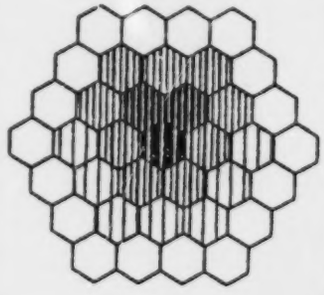
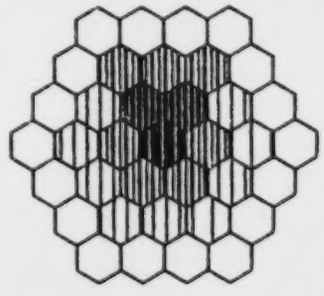
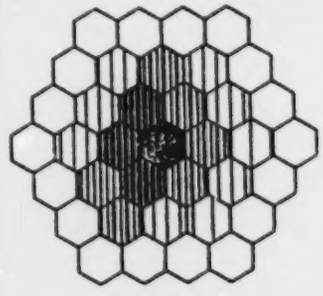
	$b^1=.7\ b^2=.3$	$b^1=.9\ b^2=.5$	$b^1=1.1\ b^2=.7$	$b^1=1.3\ b^2=.9$
$R0^1=.0016$				
$R0^1=.0017$				

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FIGURE 3.29. DISTRIBUTION OF TOTAL EMPLOYMENT FOR CHANGING PERCEPTIONS OF THE TRANSPORTATION COSTS

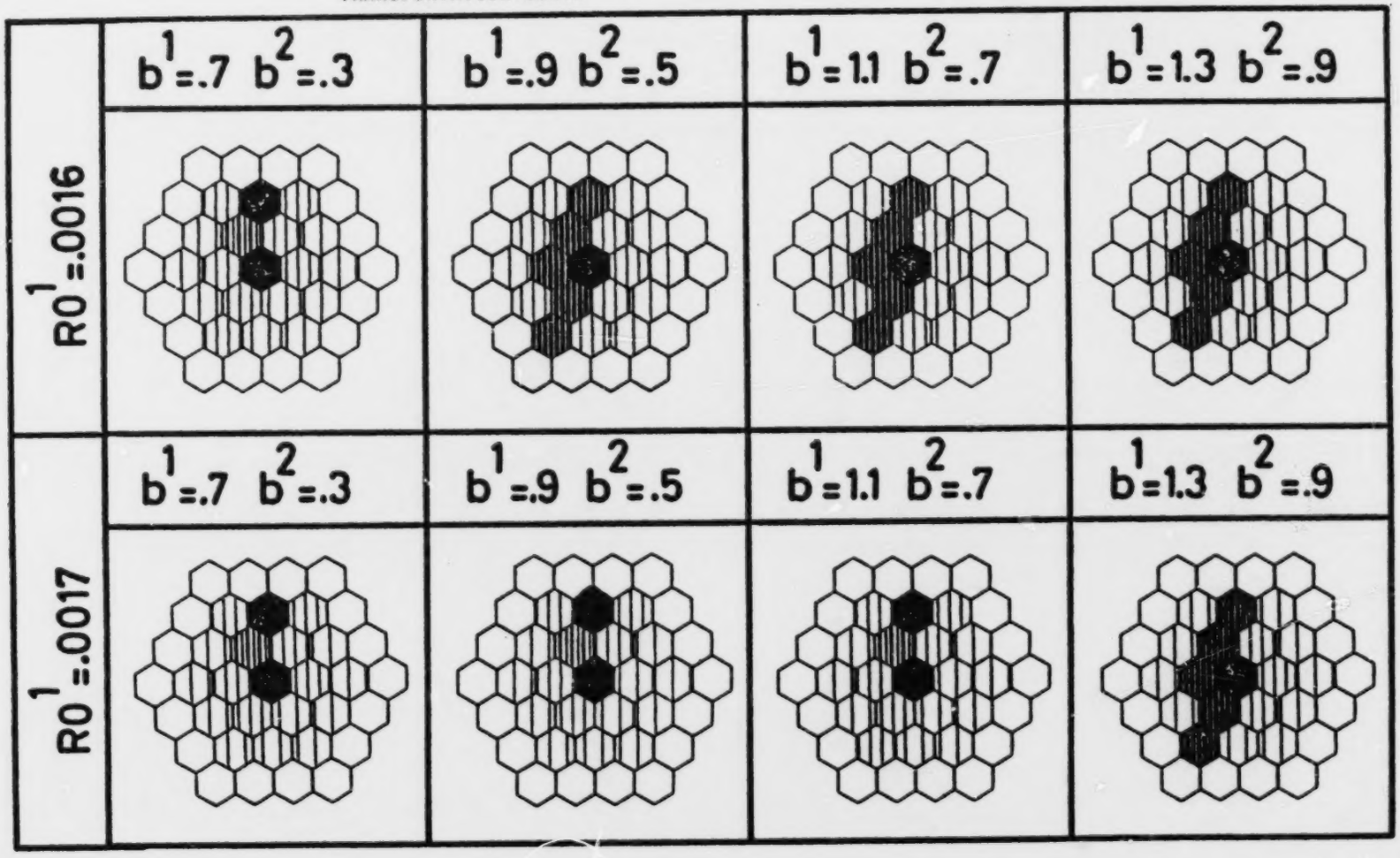

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Table 3.5. Value of the total employment (E_T) and the total population (P_T) in the center of the city.

	b^1:.7 b^2:.3		b^1:.9 b^2:.5		b^1:1.1 b^2:.7		b^1:1.3 b^2:.9	
	E_T	P_T	E_T	P_T	E_T	P_T	E_T	P_T
ρ^1 : 0016	549	217	609	315	668	422	744	550
ρ^1 : 0017	546	214	585	286	641	387	742	548

Figure 3.32 shows that the location quotient which is the proportion of the blue collar residents in every point against the proportion of blue-collar residents for the whole city is strongly affected by changing the values of b^1.

The following table (3.6) gives the values of the concentration index TI for all the variables for the different values of b^1.

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FIGURE 3.30. DISTRIBUTION OF TOTAL POPULATION FOR CHANGING PERCEPTIONS OF THE TRANSPORTATION COSTS

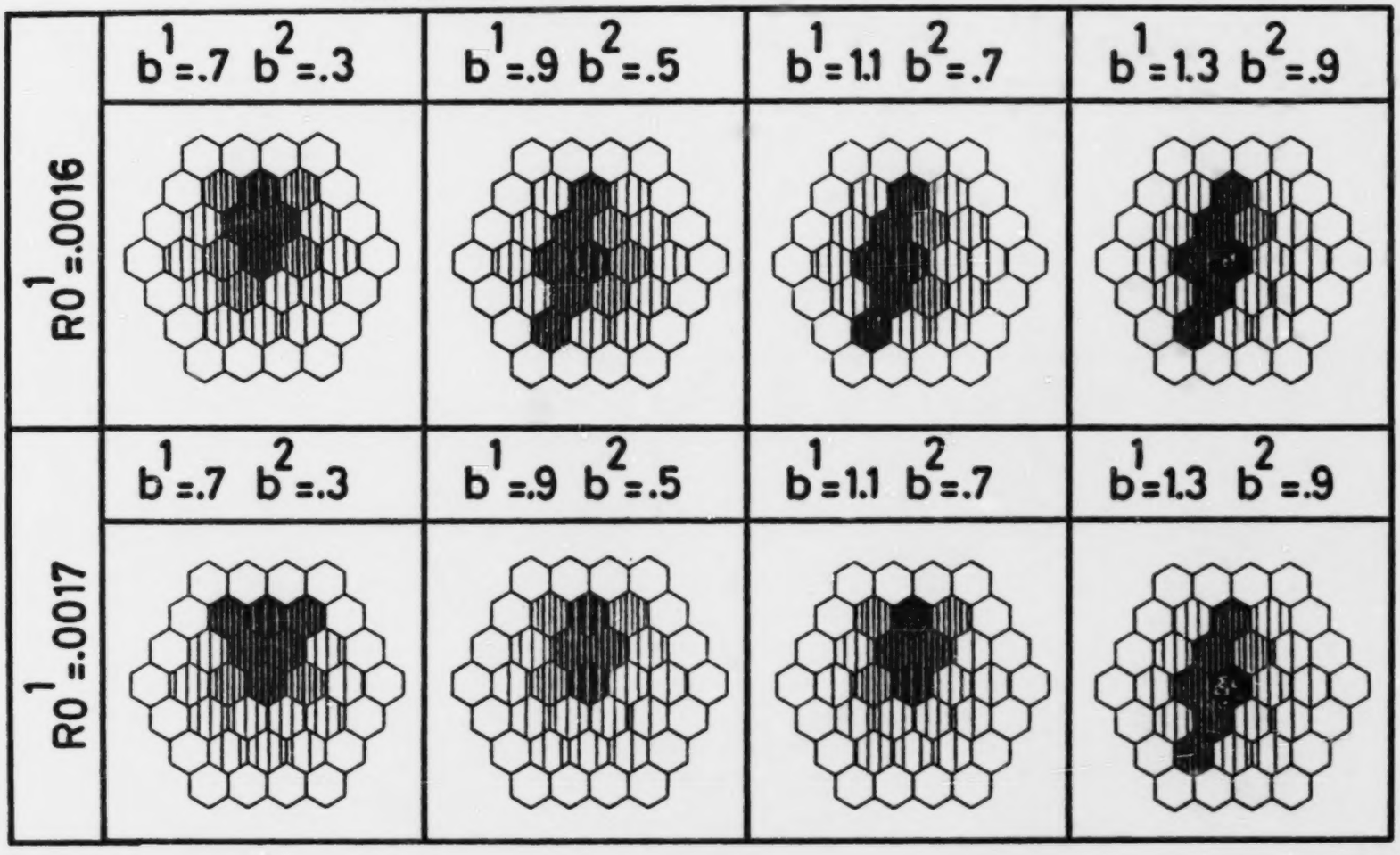

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FIGURE 3.31. DISTRIBUTION OF TOTAL DENSITY (JOBS + RESIDENTS) FOR CHANGING PERCEPTIONS OF THE TRANSPORTATION COSTS

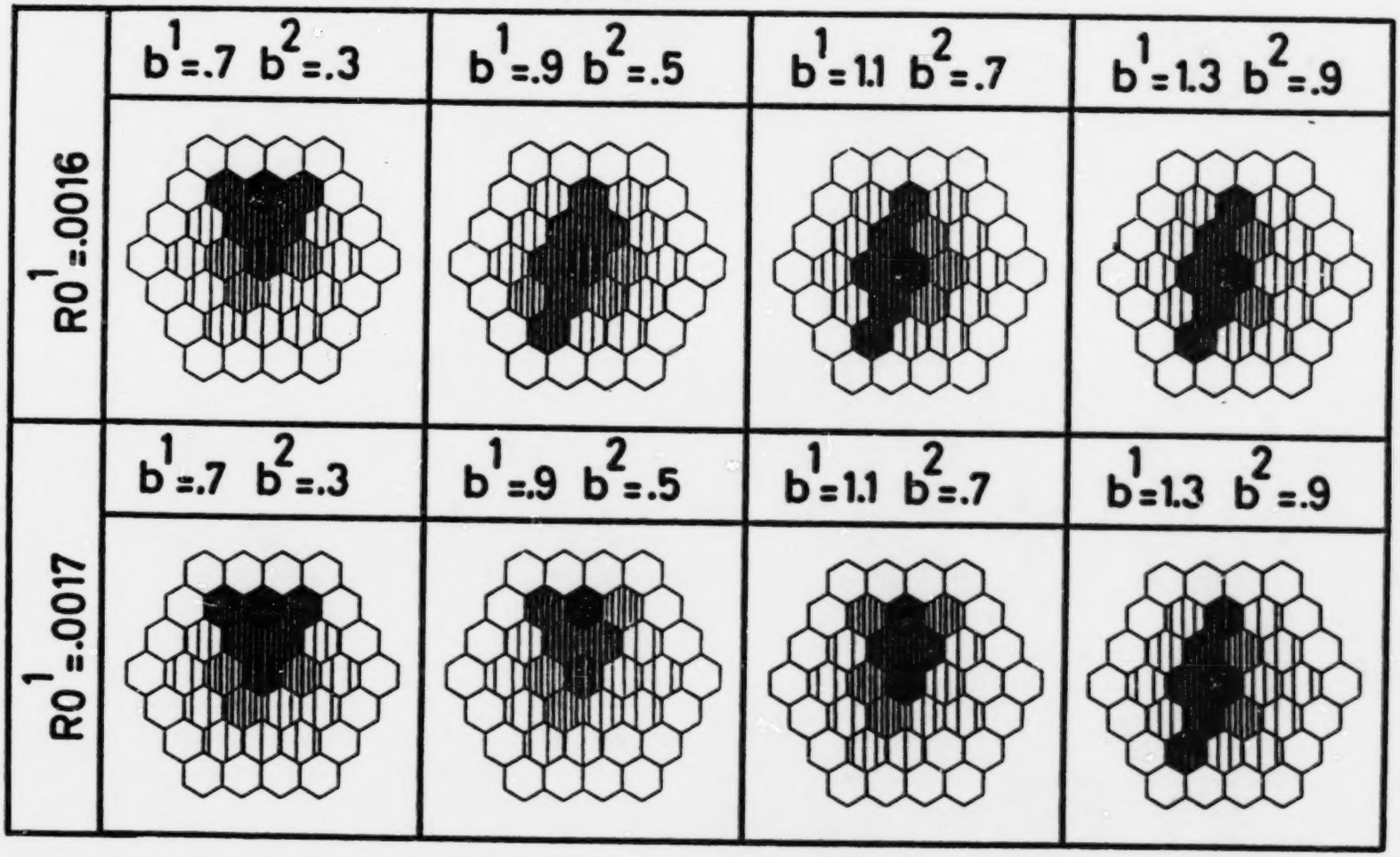

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Table 3.6. Values of the concentration index in function of b^t (TI).

	Exp. ind.	Exp. Tert.	Elementary Loc. Tert.	Rare local Tertiary	Local ind.	blue-collar residents	white-collar residents
ρ^1 : 0016							
b^1 : .7 b^2 : .3	222	172	19	16	36	106	32
b^1 : .9 b^2 : .5	57	172	19	22	16	64	48
b^1 : 1.1 b^2 : .7	53	173	27	32	22	78	74
b^1 : 1.3 b^2 : .9	51	173	36	45	30	94	107
ρ^1 : 0017							
b^1 : .7 b^2 : .3	246	172	20	17	40	115	32
b^1 : .9 b^2 : .5	232	172	21	44	44	155	46
b^1 : 1.1 b^2 : .7	210	172	34	29	44	180	69
b^1 : 1.3 b^2 : .9	56	173	36	44	30	94	107

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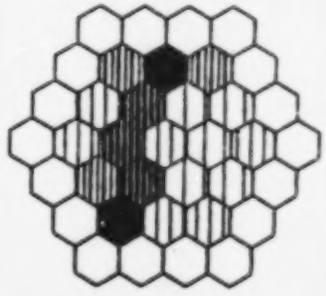
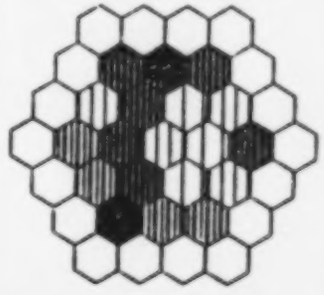
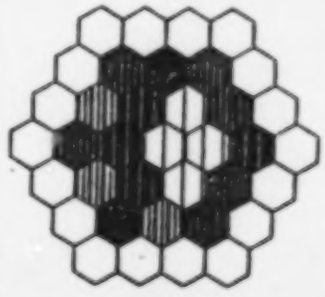
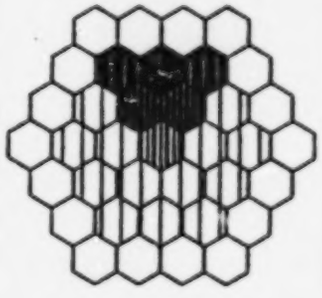
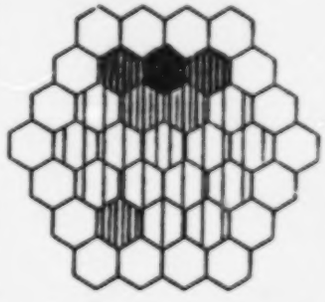
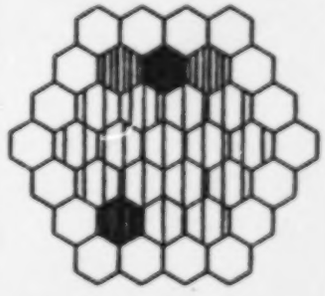
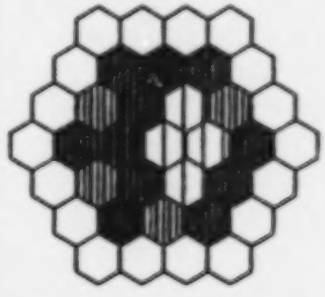
FIGURE 3.32. LOCATION QUOTIENTS (BLUE-COLLAR - TOTAL POPULATION) FOR CHANGING PERCEPTIONS OF THE TRANSPORTATION COSTS

	$b^1=.7\ b^2=.3$	$b^1=.9\ b^2=.5$	$b^1=1.1\ b^2=.7$	$b^1=1.3\ b^2=.9$
$RO^1=.0016$				
$RO^1=.0017$				

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In general the concentration index increases with the importance accorded by the population to the transportation cost. But the values of this index related to the local industry and the blue-collar residents falls when exporting industry passes from a concentrated structure to a dispersed one. Moreover, index values for exporting industry decrease for increasing values of b^1 showing the tendency to disperaion of exporting industry when b^1 is large.

CONCLUSION - THE FUNCTIONNING COST OF AN URBAN STRUCTURE

In these simulations, we have analyzed the impact on the urban structure of two parameters. The first one (internal cooperativity of exporting industry) escapes the planner's control but the second one (relative transportation costs) is among the things a planner is sometimes able to manipulate. So it may be interesting to go a little further in the analysis of the functionning characteristics of an urban structure.

The change of transportation costs for residents which modifies the individuals attitudes of people towards the journey-to-work totally reorganizes the city. At the final state, there is a stable urban structure whose characteristics weigh more on some of the urban actors than on the others. Who are the winners and the losers?

As we see from tables 3.7 and 3.8, the average distances change much from one simulation to another.

The residents, directly affected by this change, considerably shorten their journey-to-work. This induces an increase of the average haulage distance of the local economic functions. The total average distance decreases much so that these increases in the transportation cost seem to lead to a to-

TABLE 3.7. - Average travel distances.

Changes in transportation costs for residents	Mean haulage distance			Average commuting distance		Total Average Distance
	Elementary Local Tertiary	Rare local Tertiary	Local Industry	Blue-collar Residents	White-collar Residents	
ρ^1 : 0016						
b^1 : .7 b^2 : .3	.503	2.79	1.33	2.15	3.79	2.41
b^1 : .9 b^2 : .5	.501	2.80	1.45	1.54	2.85	1.92
b^1 : 1.1 b^2 : .7	.502	2.83	1.50	1.18	2.14	1.59
b^1 : 1.3 b^2 : .9	.508	2.88	1.55	.933	1.60	1.35
ρ^1 : 0017						
b^1 : .7 b^2 : .3	.502	2.78	1.31	2.18	3.80	2.42
b^1 : .9 b^2 : .5	.500	2.79	1.36	1.62	2.91	1.95
b^1 : 1.1 b^2 : .7	.504	2.83	1.42	1.21	2.20	1.59
b^1 : 1.3 b^2 : .9	.509	2.88	1.55	1.21	1.43	1.35

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TABLE 3.8. - Relative changes in the average travel distances.

Changes in transportation costs for residents	Mean haulage distance			Average commuting distance		Total Average Distance
	Elementary local tertiary	Rare Local Tertiary	Local Industry	Blue-collar Residents	White-collar Residents	
ρ^1 : 0016 b^1 : .7 .9 b^2 : .3 .5	- 0.4%	+ 0.4%	+ 9.0%	- 28.4%	- 24.8%	- 20.4%
b^1 : .9 1.1 b^2 : .5 .7	+ 0.2%	+ 1.1%	+ 3.4%	- 23.4%	- 24.9%	- 17.2%
b^1 : 1.1 1.3 b^2 : .7 .9	+ 1.2%	+ 1.8%	+ 3.3%	- 20.9%	- 25.2%	- 15.1%
ρ^1 : 0017 b^1 : .7 .9 b^2 : .3 .5	- 0.4%	+ 0.4%	+ 3.8%	- 25.7%	- 23.4%	- 19.4%
b^1 : .9 1.1 b^2 : .5 .7	+ 2.8%	+ 1.4%	+ 4.4%	- 25.7%	- 24.6%	- 18.5%
b^1 : 1.1 1.3 b^2 : .7 .9	+ 1.0%	+ 1.8%	+ 9.2%	---	- 35.0%	- 15.1%

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tal gain for the whole community.

But when we look at the results in terms of functionning costs, the situations are more complex (tables 3.9 and 3.10). The average funtionning cost of the whole city first increases and then decreases. The blue-collar residents appear as the obvious winners of the game : an increase of their transportation costs makes their average commuting cost decrease, which is quite surprising. Finally, on the whole, it is the white-collar resident and the local industry on whose shoulders the changes weigh the most.

These results clearly illustrate again the fact that small changes can have very counter-intuitive effects in such complex systems as cities.

TABLE 3.9 - Average travel costs

Changes in transportation costs for residents	Mean haulage cost			Average commuting cost		Average functionning cost for the city
	Elementary local tertiary $\phi^3 = .5$	Rare local Tertiary $\phi^4 = .05$	Local Industry $\phi^5 = .1$	Blue-collar Residents b^1 varies	White-collar Residents b^2 varies	
$\rho^1 : 0016$						
$b^1 : .7 \quad b^2 : .3$	.252	.140	1.33	<u>1.506</u>	1.136	.984
$b^1 : .9 \quad b^2 : .5$	.251	.140	1.45	1.389	1.425	<u>1.013</u>
$b^1 : 1.1 \quad b^2 : .7$	.251	.142	1.50	1.298	<u>1.497</u>	.994
$b^1 : 1.3 \quad b^2 : .9$	<u>.254</u>	<u>.144</u>	<u>.155</u>	1.212	1.436	.942
$\rho^1 : 0017$						
$b^1 : .7 \quad b^2 : .3$	.251	.139	.131	<u>1.526</u>	1.141	.994
$b^1 : .9 \quad b^2 : .5$	.250	.140	.136	1.456	1.456	<u>1.049</u>
$b^1 : 1.1 \quad b^2 : .7$	.252	.142	.142	1.213	<u>1.540</u>	.975
$b^1 : 1.3 \quad b^2 : .9$	<u>.255</u>	<u>.144</u>	<u>.155</u>	1.210	1.435	.941

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TABLE 3.10. - Relative changes in the average travel costs.

Changes in transportation costs for residents	Mean haulage cost			Average commuting cost		Average functionning cost for the city
	Elementary local tertiary	Rare local Tertiary	Local Industry	Blue-collar Residents	White-collar Residents	
^{1} : 0016						
b^1 : .7 .9 (+ 29%) b^2 : .3 .5 (+ 67%)	- 0.4%	+ 0.4%	+ 9.0%	- 8%	+ 25%	- 2.9%
b^1 : .9 1.1 (+ 22%) b^2 : .5 .7 (+ 40%)	+ 0.2%	+ 1.1%	+ 3.4%	- 7%	+ 5%	- 1.9%
b^1 : 1.1 1.3 (+ 18%) b^2 : .7 .9 (+ 29%)	+ 1.2%	+ 1.8%	+ 3.3%	- 7%	- 5%	- 5.2%
^{1} : 0017						
b^1 : .7 .9 (+ 29%) b^2 : .3 .5 (+ 67%)	- 0.4%	+ 0.4%	+ 3.8%	- 5%	+ 28%	+ 5.5%
b^1 : .9 1.1 (+ 22%) b^2 : .5 .7 (+ 40%)	+ 2.8%	+ 1.4%	+ 4.4%	- 17%	+ 5%	- 7.1%
b^1 : 1.1 1.3 (+ 18%) b^2 : .7 .9 (+ 29%)	+ 1.0%	+ 1.8%	+ 9.2%	- 1%	- 7%	- 3.5%

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CHAPTER 4 - URBAN DYNAMICS WITH EXPLICIT INTRODUCTION OF A TRANSPORTATION SYSTEM.

I. - THEORETICAL CONSTRUCTION OF A TRANSPORTATION SYSTEM

I.A. - Introduction to accessibility.

In today's world, the relations and connections between areas are frequently reflected in the character of transportation facilities and in the flow of trafic. Consequently the study of transportation is maintained by some geographers and economists to provide a deeper insight into the meaning of areal differences and even to provide a key for measuring differences and similarities among places.

The presence or lack of transportation facilities as well as local transportation policies are main factors in structuring space. Small changes in both may lead, due to the inner dynamics of transportation itself, to drastic and definite changes in spatial structure. The examples are many : i.e. The growth of Paris to the South-East was about 180% of the mean value of the whole agglomeration due to the construction of the "autoroute du sud" from Paris to Lyon in the period 1960-1968 (1) we showed the importance of the construction of the railway Namur-Luxembourg for the deve-

lopment of the Bastogne region (2).

The appearance of the automobile, the time and space flexibility of this means of transportation, coinciding with a period of urban population growth, smaller family size, change in life style and greater spatial mobility have led to an extensive utilisation of urban space (3). In addition cheap, fast and frequent railway communications extended the commuter areas of cities and gave rise to dormitory towns in large suburbs. This was not only due to the inner dynamics of transportation, but became planned too. The premotorized city, on the other hand, was characterized by patterns of a more intensive land use. Urban interaction in both types of city is a function of land use patterns, and differences in the distribution and dispersion of urban land usages lead to a spatial imbalance of supply and demand. Due to this imbalance need for transportation is changing through time, and changes through time in transportation planning consequently influence dispersion.

To explain the spatial variation of phenomena, the term accessibility is frequently used. It is used too in explanations of the growth of towns; the location of facilities and functions; and the juxtaposition of land uses. Variations in the degree of accessibility are related to varia-

tions in population densities and land values.

Accessibility may loosely be defined as the inherent characteristic (or advantage) of a place with respect to overcoming some form of spatially operating source of friction (for example time and/or distance). In one sense the word "accessibility" means capable of being reached, thus, implying a measure of the proximity between two points. Alternatively, "accessibility" is related to the ability of a transportation system to provide a low cost and/or quick method of overcomming the distance between locations.

The importance of accessibility as an explanatory factor requires an operational form. To allow the provision of operational forms it is necessary to introduce two subsidiary notions (4) :

- Relative accessibility is defined as the degree to which two places (or points) are connected.
- Integral accessibility is defined for a given point as the degree of interconnection with all other points. The operational form of integral accessibility is regarded as being dependent upon the derivation of a set of relative accessibilities for a point. That is, the integral accessibility of the X_ith point is a scalar point function of the relative accessibilities at that

point, thus

$$A(x_i) = \sum_{j \in N} a_{ij} \qquad (5)$$

where $A(x_i)$ is the integral accessibility at the X_ith point and $a_{ij}(X_i, X_j)$ is the relative accessibility of point X_j at X_i. $a_{ij}(X_i, X_j)$ may be expressed in terms of mapped ground distance, Euclidean distance, travel time, travel cost or any composite measure. In our applications we retained both the travel time and the travel cost.

In our earlier simulations on the regional and more specific on the intra urban level, we realized the importance of paying greater attention to transportation (2). We studied the role of transportation in the spatial economy and differentiation, but didn't pay sufficient attention to the questions :

- How are economic behavior patterns influenced by the availability and nature of transportation networks?
  and
- How do changes in the transportation networks affect those patterns?

though our models are very well suited to answer them. The main problem in testing transportation policies was the lack of a differentiated communication system; so that accessibility was very homogeneous in space. In this section we

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will try to introduce a transportation system in our intra-urban model.

I.B. - Creation of a transportation system.

In the real world the communication system is a composite of many transportation modes and elements acting either in unison or in competition over a complex of networks. But no matter which type of system or subsystem is studied, however its networks can always be decomposed into origins, routes and destinations, or, more simply nodes and routes. A transportation network is then "a set of geographical locations interconnected in a system by a number of routes". The spatial structure of a transportation network is the locational pattern formed by those elements, the nodes and the routes.

The communication system we studied and which will be presented here is rather simplified and composed of two overland transportation subsystems

- the private transportation subsystem
- the public transportation subsystem

Both are made up of their own means or modes and infrastructures, but they do, as in reality, physically interact.

This is manifested for example by the rather low average speed of buses, which are hindered by private transportation. The users of both subsystems are separated clearly, as we stated that people choose one transportation subsystem to do one journey. So, people going by car to a railway station to catch the train and to continue their travel are neglected. This hypothesis implies that all points of our modelled city must be connected to both of the subsystems in order to interact.

For each subsystem a network was built up of the appropriate infrastructure and modes. For both, the set of modes X contains thus all of the 37(N) points we actually can handle with our computer model. Those points are the centers of the hexagons in the lattice we use to represent our intra urban model, and are at a distance of 3km. from each other. They may be considered to be local centers of the town. The sets of routes L (roads for the private subsystem) and K (railway-, tram-, bus and metrolines for the public subsystem) are made up of all the existing direct connections between pairs of nodes. Every route is characterized by its extreme nodes. So i.e. (X_i, X_j) L if there is a direct road between X_i and X_j.

a) The private transportation system.

We stated that all movements in the private subsystem are made by people using their own automobiles. Journeys on foot or by bicycle are excluded (in a later phase this may be changed).

The set L of routes is set up of three types of roads (fig. 4.1) : - small local roads

- major roads
- city highways

The speed at which one can move along a route and the appropriate costs of movement depend on the road's type (Table 4.1).

The values we chose for speeds and costs are close to reality for Belgium.

Table 4.1. - Costs and speeds as a function of route'stype

Route's type	Price/km in S	Speed in km/h
Small local road	.20	20.
Major road	.17	25.
City highway	.14	40.

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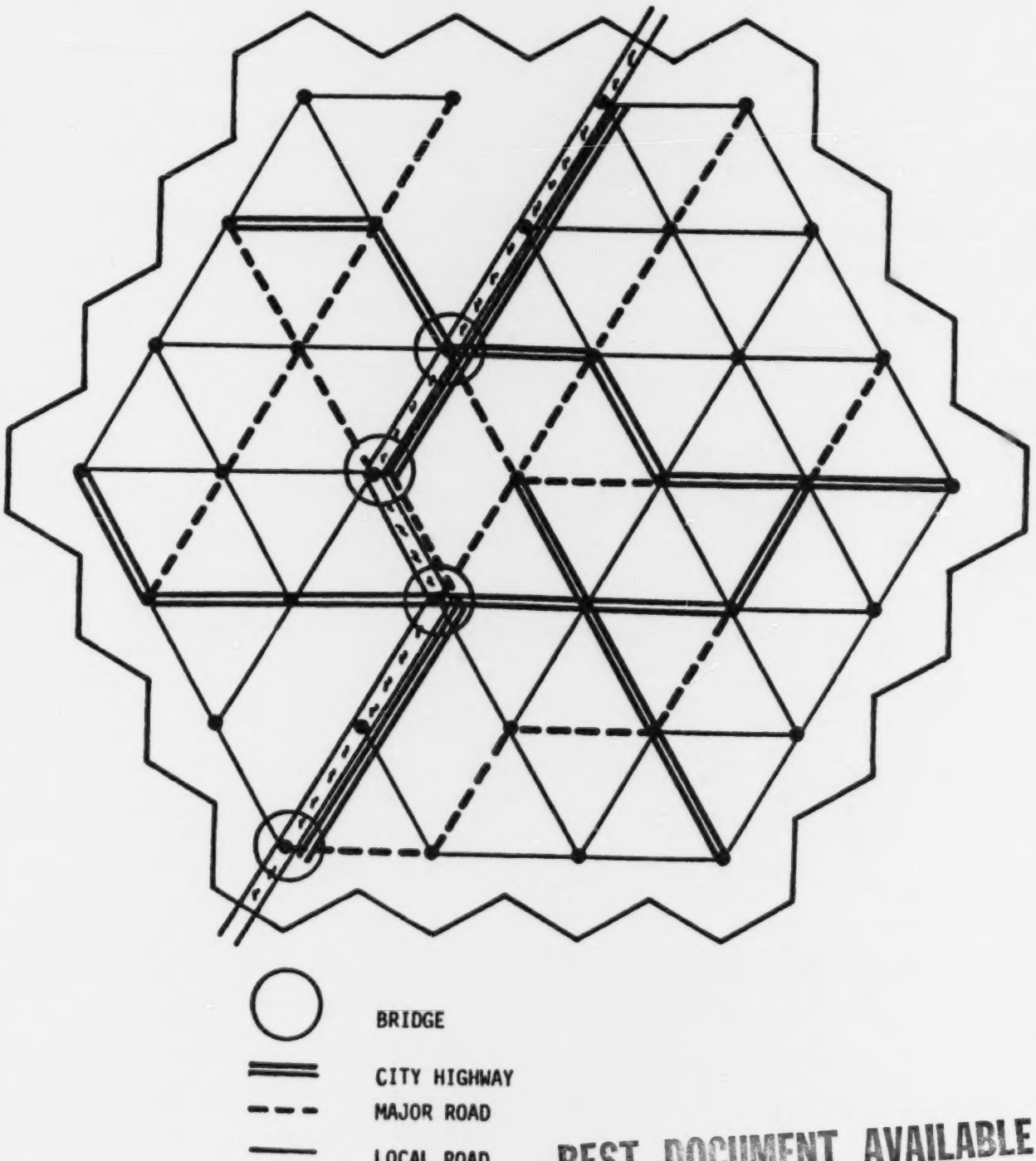
FIGURE 4.1. PRIVATE TRANSPORTATION NETWORK



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The speeds are kept rather low to get a reasonable overall speed for the city, as we didn't introduce in our model congestion in the center until now. Later on, equations and programs will be changed in order to take into account a growing congestion from the suburbs towards the city center. The costs per kilometer we proposed contain as well as petrol consumption, the payment and maintenance of the vehicule.

b) The public transportation subsystem

The public subsystem groups four public transportation modes in 1 network; containing 2 railway lines, 2 metrolines, 9 tramlines and 8 buslines (Fig.4.2., 4.3.). The set of routes K consists of all the existing direct connections, for all modes, between each pair of nodes.

People, moving by public transportation may use one or more of the 4 modes to complete their journey; but everytime they change, a waiting time, as a function of the frequency of the mode is considered. Table 4.2. summarizes : waiting time, frequency and average speed of the appropriate modes. Waiting time has been estimated to be half the period between two successive vehicules. The average speed is calculated as :

$$= \frac{\text{time to pick up passenger + time needed to drive}}{\text{total distance travelled}}$$

Table 2. Waiting times, frequencies and speeds for public modes

Mode	Waiting time in min.	Frequency in veh./hour	Speed in km/hour
Train	10.00	3	60.
Metro	3.75	8	40.
Tram	6.00	5	15.
Bus	7.30	4	20.

It was stated that metro, tram and bus stopped at least in every node on a line, while trains only stop in railway stations, indicated as big black dots on Fig.4.2. (points 6 and 19 for line 1 and points 19, 20 and 22 for line 2).

The price of a journey will also depend on the number and the type of modes used, as every mode is paid differently :

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FIGURE 4.2. PUBLIC TRANSPORTATION NETWORK: TRAIN AND SUBWAY

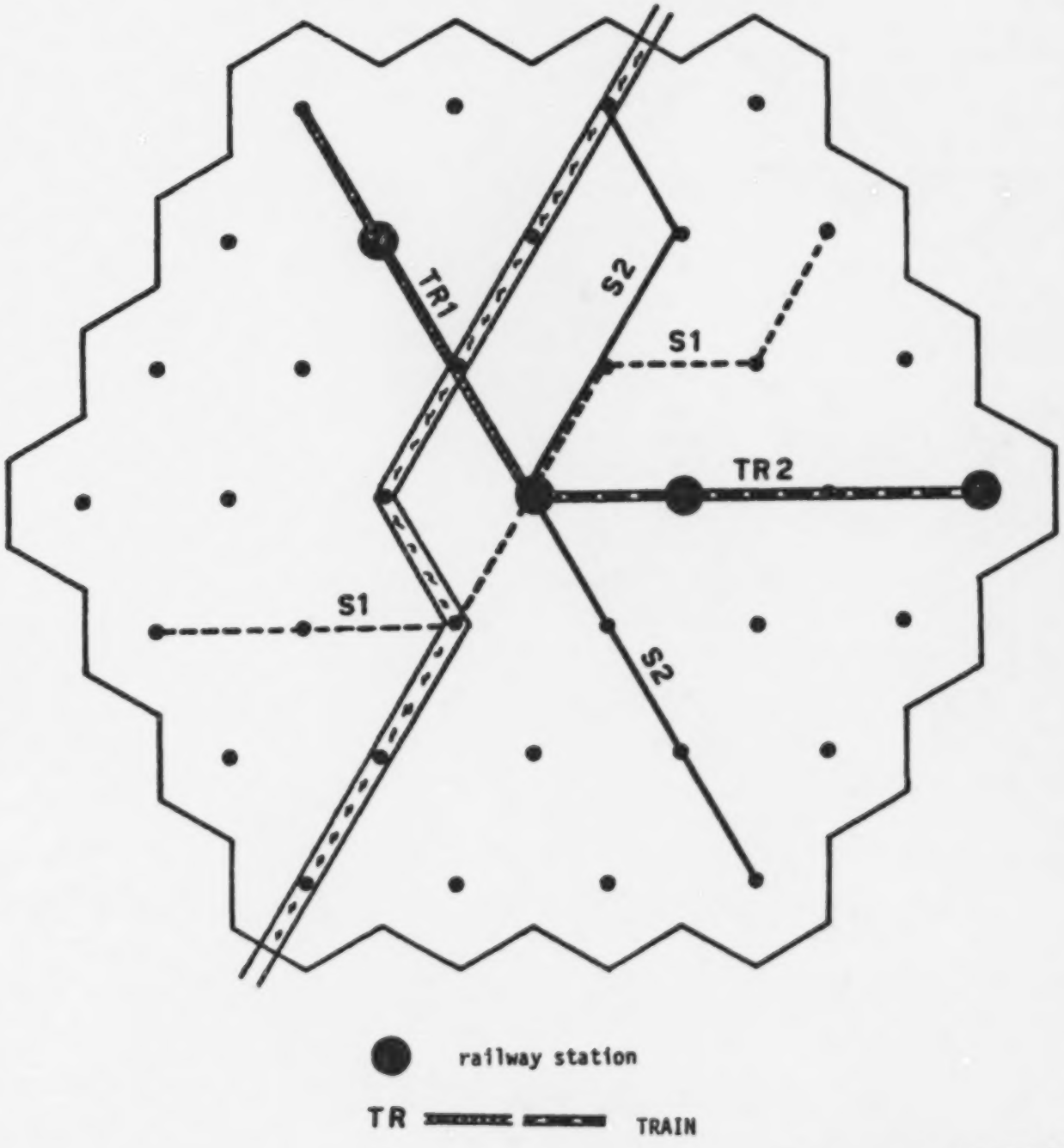

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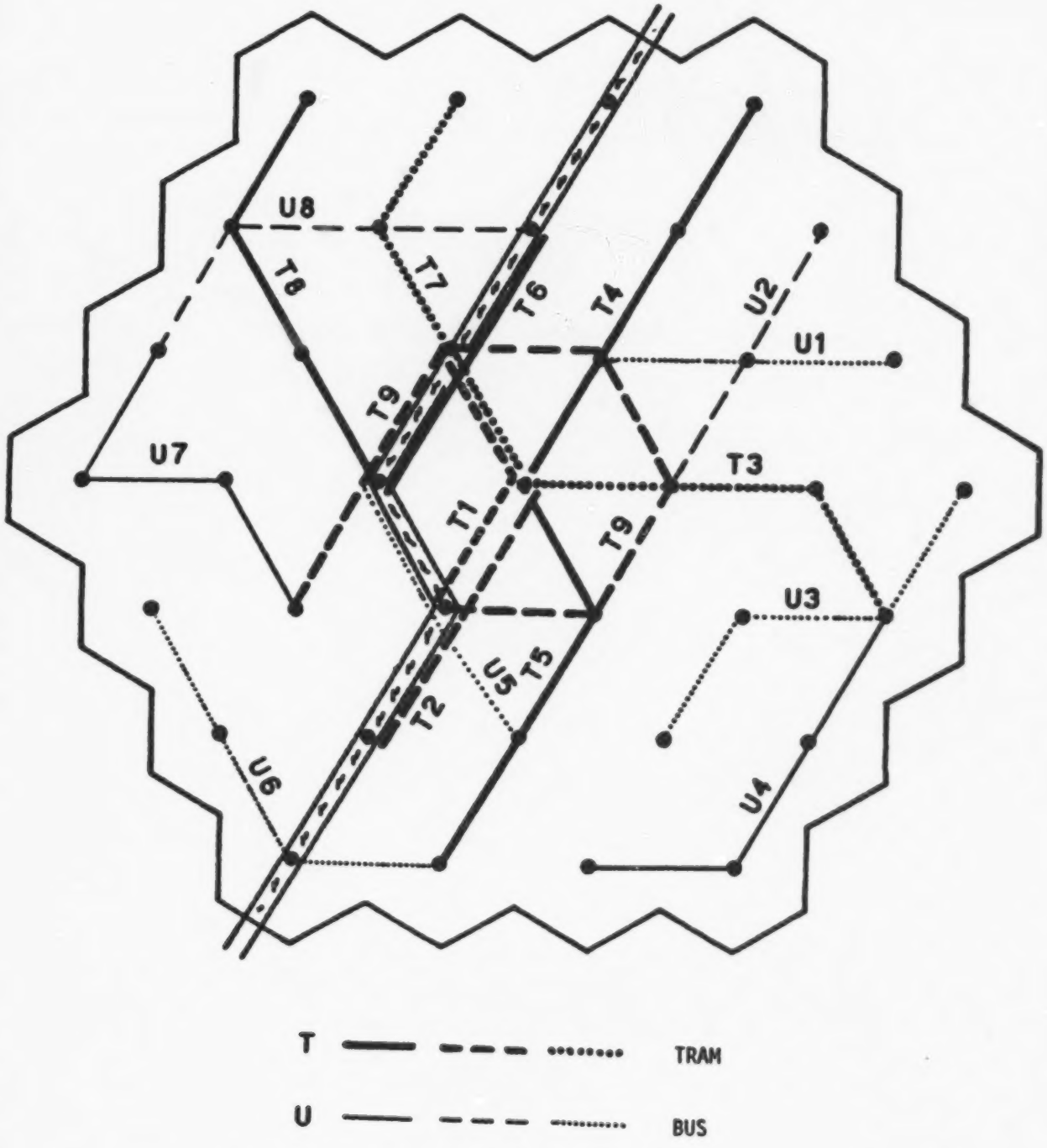
FIGURE 4.3. PUBLIC TRANSPORTATION NETWORK: TRAM AND BUS



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- Train : To use the train, passengers pay a fixed amount, independent from the trip length (.48$). Added to this they pay for every kilometer they travel (.06$/km).
- Metro : Metro users pay a fixed sum (.66$) which allows them to travel all over the subway network. In this case price does not depend on the length of the journey (as long as one stays on the metro network).
- Tram and buses : The user now pays a fixed sum of .66$ everytime, he takes a bus or tram. This allows him to travel at the maximum from one terminus to the other of one line (±9km).

These different payment modes allow us, in a further approach, to test "cost scenarios", i.e.

- pay metro per kilometer (as trains)
- pay metro per line (as trams and busses)
- reduce or rise fixed metrofares
- ....

I.C. Relative accessibility

a) Definition

In order to calculate travel times or costs in the networks we made the fundamental hypothesis that all movements

within both networks are done using the "shortest path". In practice this means that all users of a subsystem know the fastest and cheapest way to move from one point (the origin) to others (destinations).
In reality this may be not always true, but it is however the optimal solution of a function that every user tries to optimize.

A path τ going from X_v to X_s in a valued network R (X, Γ, V), where X and Γ are respectively the set of nodes and the set of routes and V a function giving a value Y_{ij} to each route $(X_i X_j) \in \Gamma$ (such as distance, travel time, travel cost or any composite measure), is a set of subsequent links such that the origin of the first one is X_v and the end of the last one is X_s. The length of is the sum of the values Y_{ij} corresponding to the routes $(X_i, X_j) \in \tau$. If we note $T(\tau)$ this length, we have :

$$T(\tau) = \sum_{(x_i x_j) \in \tau} Y_{ij}$$

if $\Delta(X_v X_s)$ is the set of all the paths going from X_v to X_s, the shortest path τ' is the one for which

$$T(\tau') = \min_{\tau \in \Delta(x_v x_s)} L(\tau)$$

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The determination of the shortest path between every couple of points of a network is not trivial. This is due to the combinatorial nature of the problem and to the number of modes considered in the applications. Therefore, one needs a systematic procedure. Many shortest path algorithms have been proposed in the literature. We retained the algorithm of Dijkstra giving the shortest path between X_i and all the other points of the network (6).

Because relative accessibility is a measure of how two points X_v and X_s of the network are connected we may thus define it as the length of the shortest path between X_v and X_s.

b) Relative accessibility in the intra-urban system.

As we already suggested above, relative accessibility is introduced in the model to calculate cost and travel time related to the daily journey home-work-home. To do so we consider four valued networks :

$R\ (X,L,V_\tau^R)$: private subsystem's network where V_τ^R is a function associating to each route $X_iX_j \in L$ the travel time t_{ij}.

$R_C(X,L,V_C^R)$: private subsystem's network where V_C^R is a function associating to each route $X_iX_j \in L$ the travel cost d_{ij}.

$P(X, K, V_T^P)$: public subsystem's network where V is a function associating to each route $X_i X_j \in K$ the travel time t_j.

$P_C(X, K, V_c^P)$: public subsystem's network where V_c is a function associating to each route $X_i X_j \in K$ the travel cost d_{ij}.

According to the fundamental hypothesis saying that the user travels along the shortest path, we define the relative accessibility of a node X_i as the length (expressed in travel time or cost) of the shortest path between X_i and X_j so we have that :

$$a_T^R(x_i, x_j) = \sum_{(x_o x_s) \in \sigma_T(x_i x_j)} t_{ij}^R$$

$$a_c^R(x_i, x_j) = \sum_{(x_o x_s) \in \sigma_c(x_i x_j)} d_{ij}^R$$

$$a_T^P(x_i, x_j) = \sum_{(x_o x_s) \in \sigma_T(x_i x_j)} t_{ij}^P$$

$$a_c^P(x_i, x_j) = \sum_{(x_o x_s) \in \sigma_T(x_i x_j)} d_{ij}^P$$

If we calculate the relative accessibilities for all pairs of points in these four networks, we can summarize them in 4 matrices.

DR_T containing all $a_T^R(X_i X_j) \ \forall \ (X_i X_j) \in L$

DR_C containing all $a_C^R(X_i X_j) \ \forall \ (X_i X_j) \in L$

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DP_c containing all a $(X_i X_j)$ $\forall$ $(X_i X_j) \in K$

DP_C containing all a_c $(X_i X_j)$ $\forall$ $(X_i X_j) \in K$

Because blue- and white- collar workers are differently sensitive to travel costs and time, their choice of a transportation subsystem will be different. We stated that :

β_c^1 : sensitivity of blue-collar workers to the cost of travel

β_c^1 : sensitivity of white-collar workers to the cost of travel

with $b_c^1 > b_c^1$

β_t^1 : sensitivity of blue-collar workers to travel time

β_t^1 : sensitivity of white-collar workers to travel time

with $b_t^1 < b_t^1$.

The parameters b_c^1, b_c^1, b_t^1 , b_t^1 and the matrices DR_T , DR_C, DP_T and DP_C allow us to calculate a weighted "distance" matrix per population type k.

For every cell (D_{ij}^l) of these matrices we calculate the expressions :

$$PR_{ij}^l = \beta_T^l DR_T + \beta_c^l DR_c$$

$$PP_{ij}^l = \beta_T^l DP_T + \beta_c^l DP_c$$

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we supposed that population group i used :

- private transportation if $PR^i_{ij} \leq PP^i_{ij}$ and $D^i_{ij} = PR^i_{ij}$
- public transportation if $PP^i_{ij} > PR^i_{ij}$ and $D^i_{ij} = PP^i_{ij}$

In this way we made a choice between private and public transportation subsystems for both types of users and we got an expression (D^i_{ij}) for the length of each journey. In the model this distance (D^i_{ij}) influences, as it did before, the residential attractivity for the population group i.
Relative accessibility -in particular travel time in the private subsystem (DR_γ)- is also stated to influence the location of local functions (S^3 elementary tertiary, S^4 rare tertiary and S^5 local industry). In this case the matrix contains travel times between the function F located on the point X_i and the consumers living on point X_j).

I.D. Integral accessibility.

The integral accessibility, being a measure of connection of one point to the whole network, will influence the location of the rare local functions(S^4). It is a well known fact that rare functions try to locate in areas which may be reached very quickly by a large proportion of city-dwellers, or, in other words, which are highly accessible in

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terms of travel time, as well in public as in private transportation subsystem to the whole population of the town. We therefore calculated integral accessibility for all points in the valued networks $\mathcal{R}_T(X, L, V_T^R)$ and $\mathcal{P}_T(X, K, V_T^P)$

$$A^R(x_i) = \sum_{x_j \in N} a_T^R(x_i, x_j) \qquad \forall x_i \in N$$

$$A^P(x_i) = \sum_{x_j \in N} a_T^P(x_i, x_j) \qquad \forall x_i \in N$$

To get an integral accessibility, $AS(X_i)$, which expressed connection in both networks, we assumed that

$$AS(x_i) = \frac{A^R(x_i) + A^P(x_i)}{2}$$

This value $AS(X_i)$ will describe the pull of every mode in the model.

In part 4.II we will compare stable structures before and after the introduction of the transportation system to study the effects of introducing it.

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II. RESULTS OF A SIMULATION WITH TRANSPORTATION SYSTEM.

To study the changes in spatial structures due to an explicit transportation system, we started from a stable structure, with the exporting industry along the canal. Matrixes D^t_{ij} and integral accessibility $AS(X_i)$ are calculated to start the simulation with transportation system. All parameters are kept unchanged except for :

- the transportation cost for the local functions (elmentary tertiary (3), rare-tertiary (4) and local industry (5)
  $\phi^3 = 8$, $\phi^4 = .8$ and $\phi^5 = 1.5$
- the sensitivity of population k to travel cost (b_c) and travel time (b_t).
  Blue-collar workers : $b^1_c = .15$, $b^1_t = .8$
  White-collar workers : $b^2_c = .01$, $b^2_t = 3$.

Figure 4.4 and table 4.3 show the results of the simulation and allow to compare them with the initial structure.

We are aware of the fact that we show the effects of the rather unrealistic possibility that, starting from the initial conditions, the full detailed transportation system descends at once on the city. In reality, demand for tr[illegible]-

portation and city structure have a mutually interdependent evolution, which must be taken into account in further phases.

The introduction of the transportation system causes an important population growth of about 21%. It is the white-collar workers group that grew the most with about 30% (Table 4.3). The concentration index of table 4.3 and 4.4. show clearly the spread out of this group. On fig.4.5. we notice that white-collar workers left the center (points 18 and 19) to settle down mainly in the eastern periphery (points 8, 13, 21, 27 and 32). This part of town, as well as points 6, 24 and 25 have a good access using subway (points 3, 24, 25 and 32) and car (6, 21 and 27); which makes these zones very attractive, since they allow residents to move fastly to their work or to tertiary services, located further on.

The number of blue-collar workers grew less. This population group remains near industry (see below) such as on points 7, 12, 18 and 30 where we notice an important net blue-collar population growth after the introduction of the networks. But for blue-collar workers too, accessibility plays a role, for points such as 11 and 31, which have a low accessibility, show a net loss of blue-collar residents. On

TABLE 4.3. City totals of variables (S_T^L) and concentration indexes (TI^L) before and after introduction of transportation system.

	S_T^L		TI^L	
	init.struct	fin.struct	init.struct	fin.struc
L=1 exp. industry	729	735	56	56
L=2 exp. tertiary	443	452	175	178
L=3 element. local func.	397	752	23	30
L=4 rare local func.	665	789	42	45
L=5 local industry	337	388	32	23
L=6 blue-collar workers	1528	1754	85	90
L=7 white-collar workers	1061	1378	67	45

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FIGURE 4.4. SPATIAL DISTRIBUTION OF SIX VARIABLES IN SIMULATION WITHOUT (ABOVE) AND WITH (BELOW) TRANSPORTATION SYSTEM

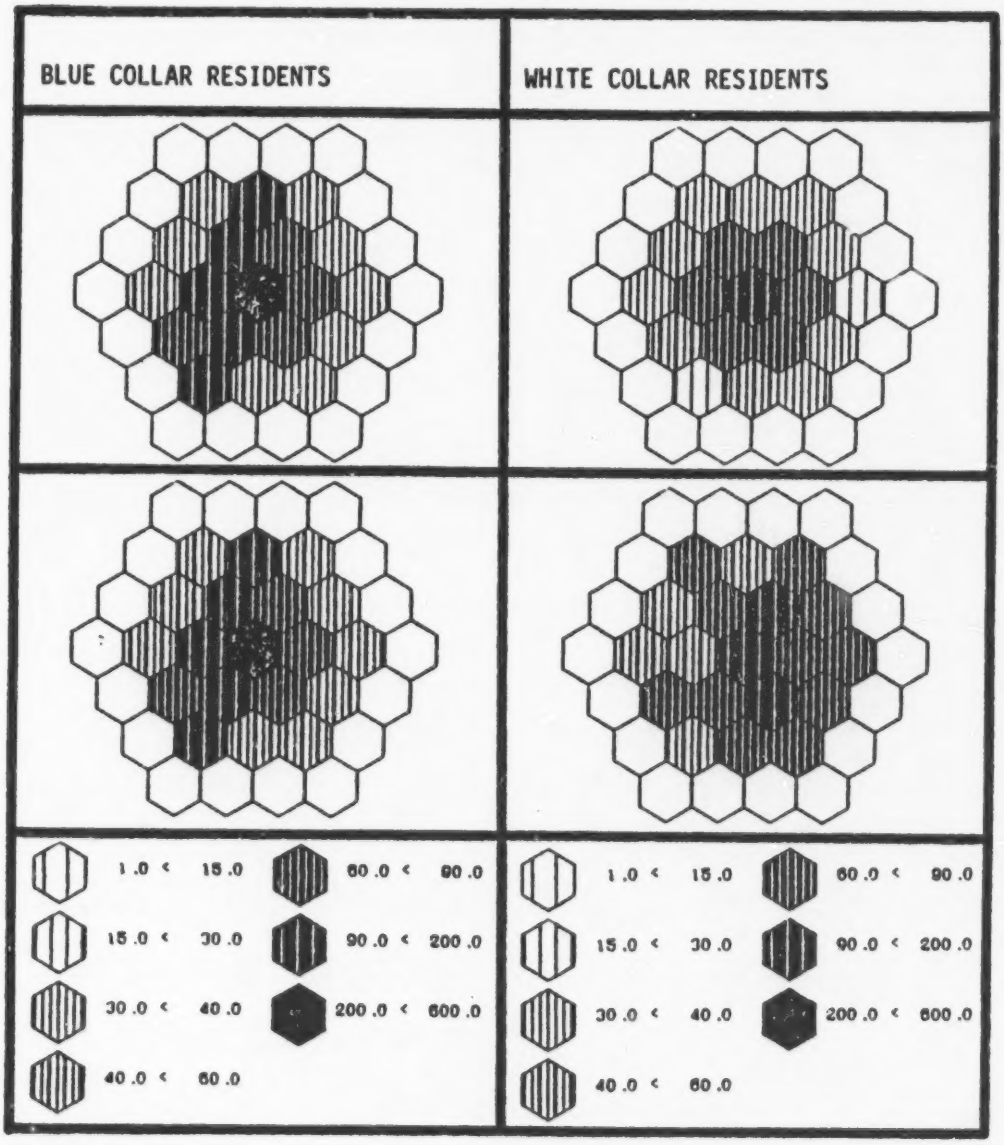

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FIGURE 4.4. CONTINUED

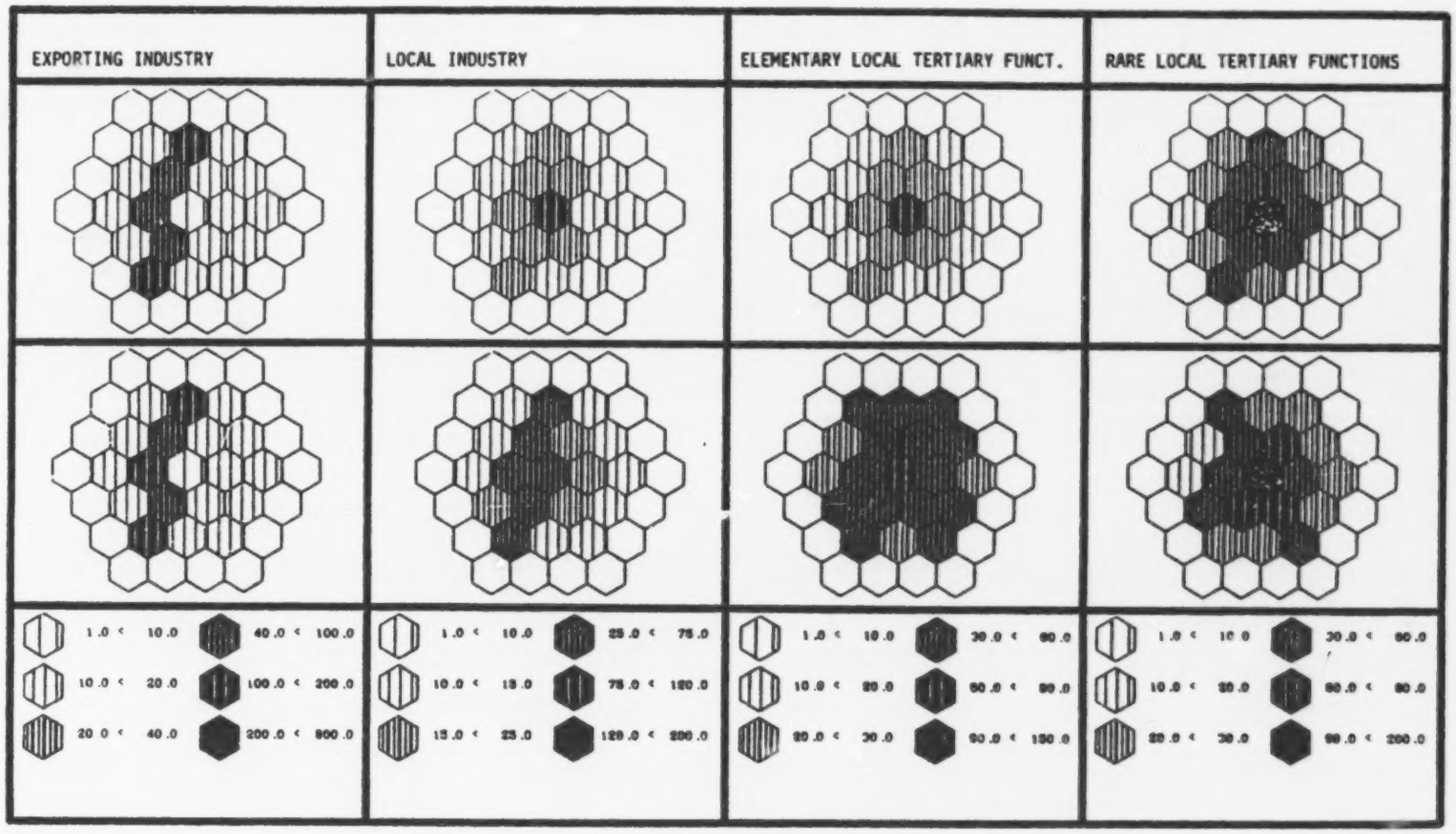

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FIGURE 4.5. EVOLUTION OF WHITE COLLAR RESIDENTS.

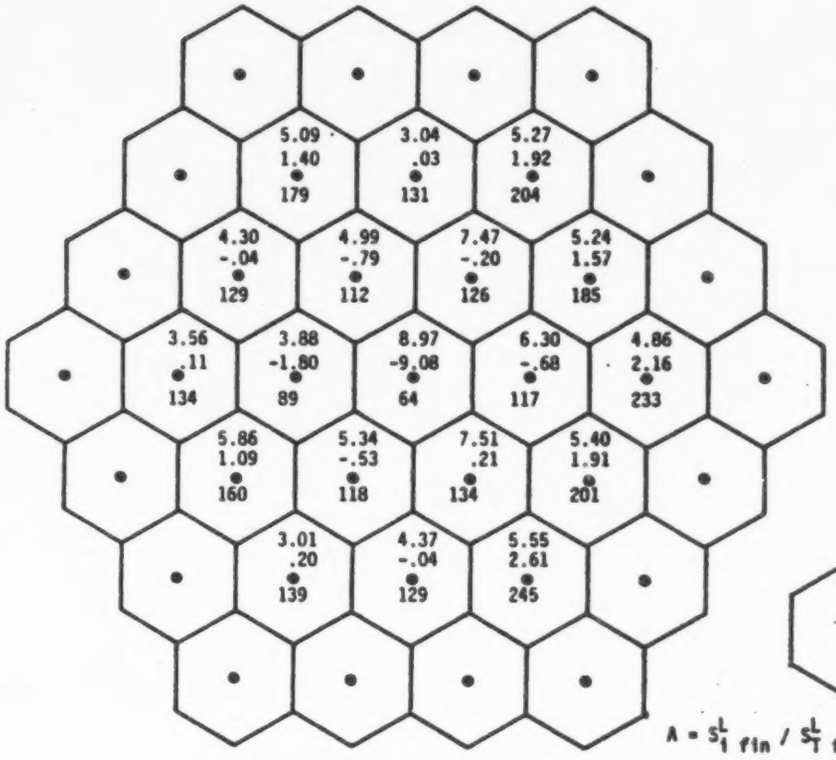
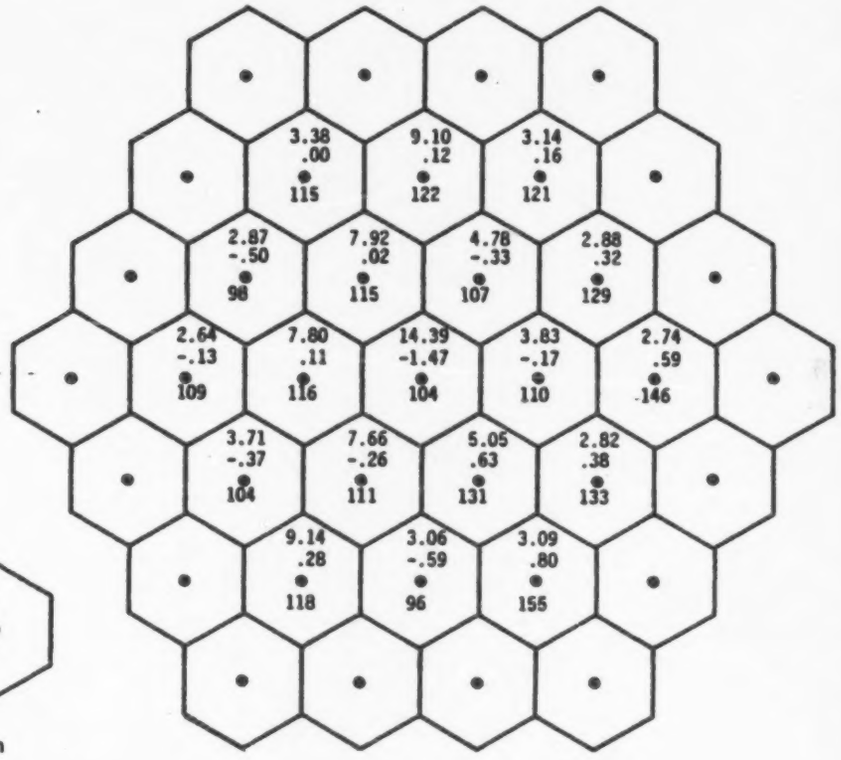


FIGURE 4.6. EVOLUTION OF BLUE COLLAR RESIDENTS



$A = S_{i\ fin}^{L} / S_{T\ fin}^{L}$

$B = (S_{i\ fin}^{L} / S_{T\ fin}^{L}) - (S_{i\ init}^{L} / S_{T\ init}^{L})$

$C = (S_{i\ fin}^{L} / S_{i\ init}^{L}) \times 100$

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the other hand, there is an important growth in the hightly accessible part of town (fig.4.6). However the total number of blue-collar residents, living in the East is relatively less important in comparison with the canal zone.

The dispersion of population principally of white-collar residents, is followed by an important growth (± 89%, see table 4.3) of the elementary tertiary functions. Growth is equally distributed over the zone with high population size (canal zone, center, eastern zone).

Also, rare tertiary functions do spread out after the introduction of the transportation system. Fig.4.7. shows clearly that rare local funtions are locating chiefly on highly accessible points, such as 6, 13, 24, 25, 26, 27 and 32. Where access is low (7, 11, 17, 30 and 31), there is a net decrease in rare tertiary jobs. In the real world this effect is well known for it is important that rare functions can be reached easily by a large proportion of inhabitants.

If is a recent evolution in European and American cities, that rare tertiary functions tend to locate in "white-collar zones", of high accessibility near the periphery of the town, thus avoiding congestion, high land prices, lack of green, air pollution and noise. Moreover, they are then

FIGURE 4.7. EVOLUTION OF RARE LOCAL FUNCTIONS.

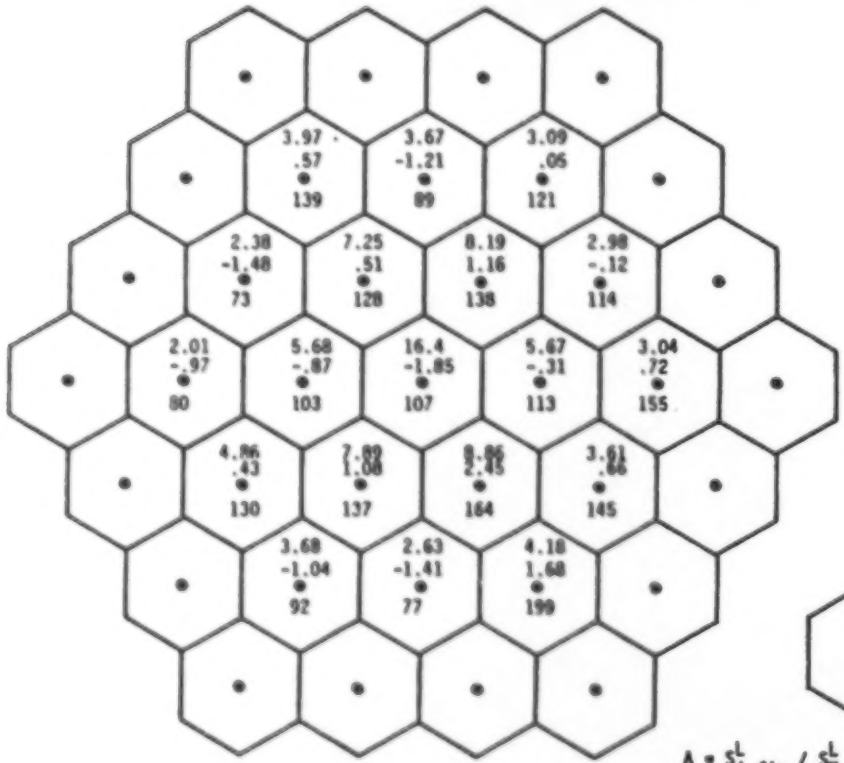
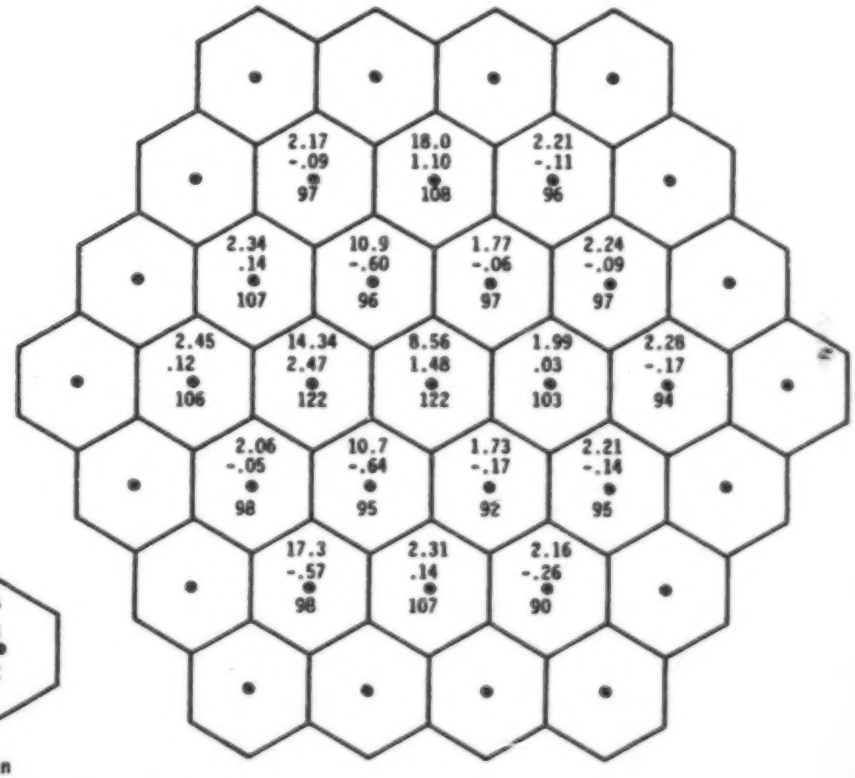


FIGURE 4.8. EVOLUTION OF EXPORTING INDUSTRIES.



$A = S^L_{i\ fin} / S^L_{T\ fin}$

$B = (S^L_{i\ fin} / S^L_{T\ fin}) - (S^L_{i\ init} / S^L_{T\ init})$

$C = (S^L_{i\ fin} / S^L_{i\ init}) \times 100$

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closer to their employees.

Exporting industry remains concentrated along the canal, but as fig.4.8 shows us, there is an industrial growth in the center too (point 18 :14.3% of ind. jobs, +2.5%, point 19 : 8.56 of ind. jobs, +1.5%). In contrast with this, we notice a slight loss of industrial jobs in the eastern part of town. In general, this evolution is contrary to that of the rare local functions.

Local industry locates near heavy industries, but leaves the city center, which loses 9% of this kind of job.

We may conclude that the introduction of the transportation system structured and polarized more clearly the town. The western part is very industrial with blue-collar workers, being sensitive to travel costs, living nearby. The eastern part with mainly white-collar residents gets an important number of jobs in rare tertiary functions. Firms locate here at highly accessible points where they can be easily reached.

III. POSSIBLE SCENARIOS OF TRANSPORTATIONS POLICIES

As mentioned in the introduction, and discussed the paragraph above, transportation not only results from the spatial distribution of social and economic activities but on the other hand it also induces and amplifies zonal specializations, dispersion, urban growth, etc... In most cases the changes result from specific transportation policies.

Our dynamic models allow us to test several of these policies and to study their effects on city structure over (long) periods of time. We plan to simulate four types of intervention imposed on the transportation system in a distinct order, which leads to seven situations, called scenario's (fig.4.9). In a further report, the changes in the transportation system, the results of the simulations corresponding to it and the effects on city-structure will be discussed at length. Here we only give a brief overview of the interventions. Together with fig.4.9. this summarizes part of the work we started very recently.

Scenario 1 : Basic scenario

Private and public transportation subsystems are as in the text above. The results of paragraph 4.II are obtained with this scenario.

Intervention 1 (IF 1) :

The tramline n°9 (the circular one on fig.4.3) will be replaced by a metroline (n°3). This will enlarge the subway network considerably.

Intervention 2 (IF 2) :

The cost of private transportation will be raised i.e. due to high energy prices. This will influence price of private made journeys only.

Intervention 3 (IF 3) :

The fares of subway will be raised too. This also might be due to energy cost.

Intervention 4 (IF 4) :

To avoid the raising of fares one also can diminish frequency. IF4 consists of halving the number of subway vehicules per hour.

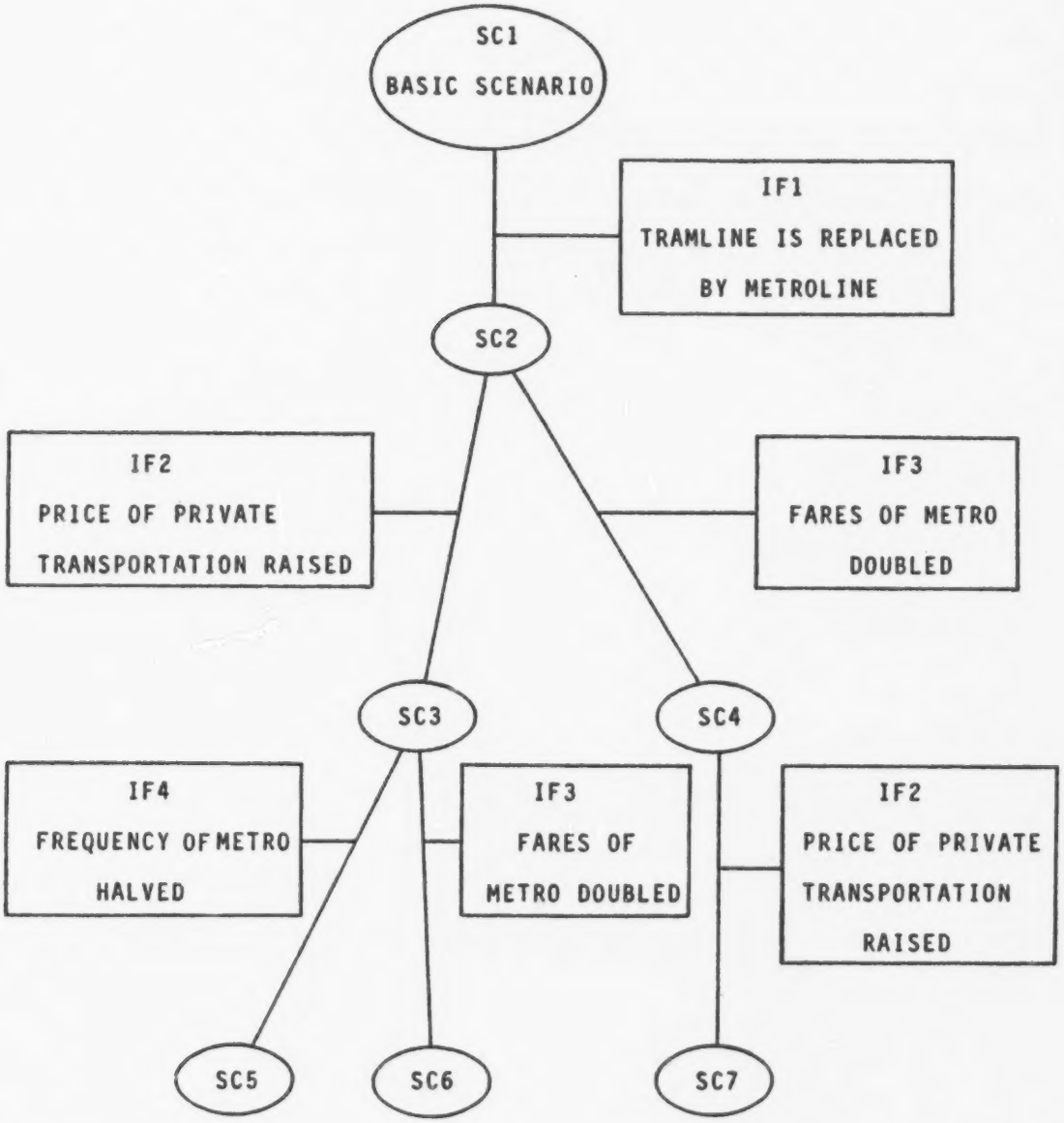

FIGURE 4.9. TRANSPORTATION POLICIES: FOUR INTERFERENCES LEADING TO SEVEN SCENARIOS.

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INTRODUCTION

The work presented in this report is the further extension of research performed under previous contracts with the Department of Transportation (TSC-1185-1460-1640). In this further work there are two basic aims being pursued simultaneously. Firstly to attemps some practical study of the evolution of urban systems is the United States using the new theoretical ideas that were developed in our earlier work. Secondly, to further extend and deepen our models and their theoretical foundations as well as clarifying and rendering explicity the mutual interaction and evolution of a transportation network and its corresponding urban structure.

In part I, concerning the application of our methods to a study of the evolution of urban structure within the United States we begin with a description and analysis of changes that have occurred over the past three decades or so. What emerges is that locational criteria for economic activities as well as for residential population have changed, possibly as a result of greater wealth, from being dominated by strictly economic evaluations, to include psychological · social considerations.

The questions we ask ourselves are therefore the following :

- What is really intrinsic to the internal structure of a city, what ever the mix of the exporting activities and their part in the total urban employment?
- What is influenced by the fluctuations coming from the outside world (variation of the mix of exporting activities)?
- What is influenced by the internal fluctuations (different possibilities of location of a given mix in the city)?
- What is influenced by the values of the parameters?
- What are the main bifurcation points?

The goal of the present work is therefore to elaborate a guide for our future theoretical simulations. Different mixes of exporting activities will be explored on a theoretical lattice in order to analyze how the nature of the mix influences the final state of the system and its evolution in time.

In order to choose economic structures not too far from reality, we have analyzed the characteristics of 101 U.S. Metropolitan Area in 1960, which were subjected to a very interesting study 10 years ago.

I. REINTERPRETATION OF THE ULLMAN DACEY AND BRODSKY STUDY ON 101 U.S. METROPOLITAN AREAS IN 1960.

Our analysis is based on the study of Ullman, Dacey and Brodsky (1) whose fundamental hypotheses are coherent with the kind of models we are dealing with. Indeed, the authors have calculated, using the "minimum requirement technique", the nature of the employment in local and exporting activities in 1960 for the 101 U.S. Metropolitan Areas having a population over 250,000 inhabitants.

In their study, they had divided the total urban employment into 12 activity types. Since we are looking for spatial structures we have grouped these 12 categories into three broad new ones, differing from each other by their main location criteria.

I.A. Manufacturing activities.

Durable and Non-Durable goods.

This first type of employment, when it is generated by the outside world, often appears in the form of large firms, needing good and cheap transportation facilities, consuming much space and employing essentially unqualified or semi-qualified workers. Looking for cheap land, it has a strong tendency to decentralize to the urban fringe when the city

grows.

I.B. Transportation, communication and wholesaling.

This second type of employment reveals a quite specific function of the city vis-à-vis the outside world. It is often located in specialized sites.

I.C. Activities tied to the population

Other tertiary activities : Finance - Public Administration - Retail - Business Services - Entertainment - Professional Services

And Construction.

When it is generated by the outside world, this third type of employment shows a strong tendency to centralize. It is the essence of the "Central Business District".

A cluster analysis was then performed on the basis of these three types of employment in order to define the different kinds of "typical" exporting activity mixes. Ten groups were isolated. Fig.5.1. shows the average characteristics of each group and the deviations from the average inside each group. The complete list of all the cities

constituting each group, with their basic employment characteristic, is given in the Appendix.

TABLE 5.1. - Typical exporting activity mixes in 1960.

	Percentage of exporting employment in the total urban employment			Population range (in million units)		Number of cities
	Manuf.	Transp. Wholesale	Other Tertiary			
Industrial cities						
Group 1	84.2	4.7	11.1	0.3	6.7	24
Group 3	65.0	10.2	24.8	0.3	6.2	20
Intermediate cities						
Group 6	41.4	17.4	41.2	0.3	2.8 (10.7)	23
Tertiary cities						
Group 8	17.8	20.7	61.5	0.3	0.9	7
Group 9	17.9	12.1	70.0	0.3	0.8	14
						88

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II. TYPICAL EXPORTING ACTIVITY MIXES

The ten groups we isolated cover the whole spectrum of possibilities from the highly industrialized city to that of a highly degree of specialization in regional tertiary functions. The size of the groups varying much, only 4 or 5 among them appear as "typical" (table 5.1.).

II.A. Industrial cities.

Almost half of the metropolitan areas considered (48) showed in 1960 a high degree of specialization of their exchanges with the outside world in manufacturing activities. This characteristic doesn't seem to be related to their size since one can find it in Erie, Pa as well as in Los Angeles. Nevertheless, let us notice that all the large american metropolitan areas of over 3,000,000 population, except New York, fall into this category.

Twenty-four cities (group 1) live almost exclusively from manufacturing exchanges while twenty others (group 3) emphasize a bit more their functions of regional tertiary pole and transportation node.

Inside this category of industrial cities, it will be

interesting to analyze the influence of the size of the city, as well as the influence of the relative decrease of the part of the employment generated by the outside world in the total urban employment (this goes from 48% in Erie to 32% in Los Angeles), on the spatial structure of the city.

Almost all of these cities are located in what is traditionally called the heartland of the country (fig.5.2).

II.B. Intermediate cities.

Almost a third of the American Metropolitan Areas (30) show a much more balanced structure of their exchanges with the outside world. Twenty-three of them form a group (group 6) of which average employment structure gives an equal importance to manufacturing and tertiary functions and a relatively high percentage to transportation and wholesaling.

In the country, they are located at the periphery of the industrial cities, in less urbanized areas but still in contact with the heartland (fig.5.3).

Their size is smaller, except for New York which is the

FIGURE 5.2. LOCATION OF THE INDUSTRIAL CITIES (1960)

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FIGURE 5.3. LOCATION OF THE INTERMEDIATE CITIES (1960)

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only large metropolis of this category.

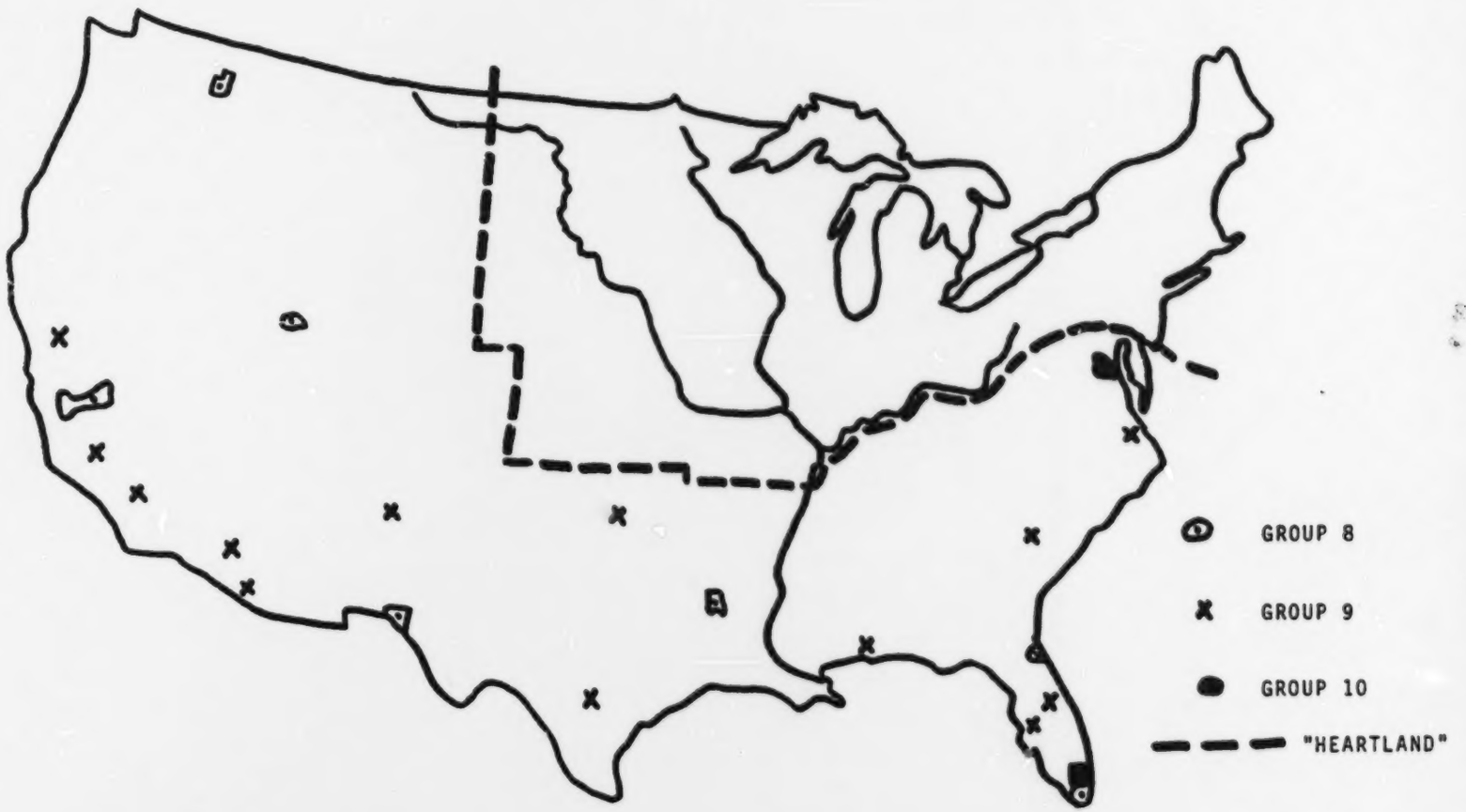
II.C. Tertiary cities.

The last fourth (23) of the American Metropolitan Areas, are highly specialized in tertiary functions, with a different emphasis on transportation and wholesaling (groups 8 and 9).

All of them have less than one million inhabitants, except Washington whose structure is rather unique since it has no exporting manufacturing activities. (This might be due to the fact that the administrative limits of Washington do not include much of the periphery).

These tertiary cities are all located in what is traditionally called the hinterland of the country. They are the regional poles of the rural areas (fig.5.4).

FIGURE 5.4. LOCATION OF THE TERTIARY CITIES (1960)



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III. CONCLUSION

III.A. City size and structure of the exchanges with the outside world.

There seems to exist a link between the nature of the exporting employment mix and the size of a city. A city can become a large metropolis only if more than half of its employment generated by external demands is devoted to manufacturing activities. This sounds logical since these activities have a stronger multiplying effect than the others which are mainly induced by the presence of the population.

On the other hand, these activities have quite specific location criteria, which give them a strong structuring effect on the organization of space. Would that mean that a large metropolis is proportionally more than another conditioned by this type of constraint?

III.B. Regional location of a city and structure of its exchanges with the outside world.

The location in the country of the structures of exchange (fig.5.5) is much less random than expected. It is organized in more or less concentric circles around the

FIGURE 5.5. NATURE OF THE EXCHANGES WITH THE OUTSIDE WORLD. SPATIAL DISTRIBUTION (1960)

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Great Lakes, pointing out the existence of a gradient of industrialization. It is the physical expression of the heartland-hinterland regional relationships which have been produced by a series of historical and economic factors grafted in a particular geological context.

Therefore, there might exist a stronger causal link (thus deterministic in nature), than thought before, between the economic history of the national space and the internal structure of the cities, i.e. between the two extremes of the scale of spatial structures.

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CHAPTER 5

(1) see reference 7 of part one.

APPENDICES

1 - Relationship between the size of a city and the external demand.

2 - The Economic structure of Liege, Belgium in 1961.

3 - Induction rates of employment in elementary tertiary functions.

4 - Induction rates of employment in rare tertiary functions.

5 - Employment characteristics of 101 U.S. Metropolitan Areas over 250,000 in 1960.

1 - RELATIONSHIP BETWEEN THE SIZE OF A CITY AND THE EXTERNAL DEMAND.

Employment in :

City sizes (in thousands inh.)	Local activities	Exporting activities
American Metropolitan Areas/1960 (1) size categories		
2.5 - 3.0	23%	77%
10.0 - 12.5	30%	70%
25.0 - 40.0	41%	59%
100.0 - 150.0	44%	56%
300.0 - 800.0	50%	50%
1,000.0	54%	46%
Cities in Southern Belgium/1961 (2) Average size		
10.5	25%	75%
18.7	33%	67%
60.4	44%	56%

(1) from Ullman, Dacey and Brodsky

(2) private communication from Urbs Nova, Belgium. Both studies used the minimum requirement technique for the calculation of the local employment.

2 - THE ECONOMIC STRUCTURE OF LIEGE, BELGIUM IN 1961.

	Number of units	
Jobs		
Exporting industries	97,685	
Exporting tertiary activities	16,181	
Total		113,866
Elementary tertiary functions	21,476	
Rare tertiary functions	50,722	
Local industry	31,424	
Total		103,622
Total employment		217,488
Active population		
Blue-collar workers	90,859	
Employees	81,970	
Total		172,829

Coefficient of employment = 1,26
(jobs/actives).

3 - INDUCTION RATES OF EMPLOYMENT IN ELEMENTARY TERTIARY FUNCTIONS.

In 1961, 172,829 working people were living in the city of Liège, Belgium. 90,859 were considered as blue-collar workers (W). 81,970 were considered as employees (E).

In 1973, in the Province including the city of Liège, the ratio of family consumption of these two categories of people was the following :

$$\frac{\text{consumption of E}}{\text{consumption of W}} \qquad 1.33$$

If a family of W represents one unit of consumption, the total number of units of comsumption for Liège is :

$$90{,}859 + (81{,}970 \times 1.33) = 199{,}879 \text{ units}$$

In Liège in 1961, there were 21,476 jobs in elementary tertiary activities. The rate of employment induction of one unit of consumption can then be estimated as

$$\frac{21{,}476}{199{,}879} = 0.1074$$

This means that one blue-collar worker (and his family) induces .1074 local tertiary jobs and one employee (and his family) induces

$$\frac{21{,}476 - (90{,}859 \times .1074)}{81{,}970} = .1429 \text{ jobs}$$

4 - INDUCTION RATES OF EMPLOYMENT IN RARE TERTIARY FUNCTIONS AND LOCAL INDUSTRY.

4.1. Induction of local industry by exporting industries

12,542 jobs in local industry were directly related to exporting industry which represented 97,685 jobs in 1961 in the city of Liège, Belgium.
We can then say, in a first approximation, that one job in exporting industries induces :

$$\frac{12,542}{97,685} = .1284 \text{ jobs in local industry}$$

4.2. Induction of rare tertiary functions and local industry jobs by the population.

For this calculus, the two types of jobs have been agglomerated.
60,604 jobs (rare tertiary activities + local industry related to population) were induced by the 199,879 units of consumption considered before (see Appendix 2). Then, one blue-collar worker (and his family) induces :

$$\frac{69,604}{199,879} = .3482 \text{ jobs of the two types}$$

and one employee (and his family), induces :

$$\frac{69,604 - (90,859 \times .3482)}{81,970} = .4632 \text{ jobs of the two types}$$

5 - EMPLOYMENT CHARACTERISTICS OF 101 U.S. METROPOLITAN AREAS OVER 250,000 IN 1960.

Types of metropolitan areas	Population in 1,000,000	Structure of the employment in exporting activities (the sum equals 100%)			Structure of total employment (the sum of the 3 equals 100%)				
		Manuf.	Tr+Wh.	Other Tert.	Export	Local	Carrying capacity Total	Agric	Mining
INDUSTRIAL CITIES									
Group 1 - Highly specialized in manufacturing									
Average of the group :		84.2	4.7	11.1					
- Los Angeles - Long Beach, Calif.	6.7	74.0	4.4	21.6	32.3	66.0	1.7	(1.4)	(.3)
- Philadelphia, Pa. - N.J.	4.3	83.5	4.8	11.7	35.0	63.7	1.3	(1.2)	(.1)
- Detroit, Mich.	3.8	91.4	2.6	6.0	35.9	63.4	.7	(.6)	(.1)
- Pittsburgh, Pa.	2.4	82.1	8.6	9.3	36.9	60.8	2.3	(.9)	(1.4)
- Cleveland, Ohio	1.8	83.1	7.7	9.2	40.2	59.2	.6	(.5)	(.1)
- Newark, N.J.	1.7	76.1	6.6	17.3	40.5	58.9	.6	(.5)	(.1)
- Buffalo, N.Y.	1.3	79.5	8.3	12.2	41.1	57.6	1.3	(1.2)	(.1)
- Milwaukee, Wis.	1.2	84.0	5.7	10.3	41.7	57.3	1.0	(.9)	(.1)
- Providence, Pawtucket, R.I., Mass.	.8	88.1	.8	11.1	43.8	55.2	1.0	(1.0)	(-)
- Rochester, N.Y.	.6	85.6	1.6	12.8	45.3	53.4	1.3	(1.3)	(-)
- Gary-Hammond - East Chicago, Ind.	.6	91.4	5.3	3.3	45.4	53.4	1.2	(1.2)	(-)
- Akron, Ohio	.5	84.8	5.7	9.5	46.7	52.5	.8	(.7)	(.1)
- Youngstown - Warren, Ohio	.5	87.9	3.6	8.5	45.9	52.4	1.7	(1.5)	(.2)

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- Allentown - Bethlehem - Easton, Pa-N.J	.5	93.5	4.1	2.4	44.8	52.4	2.8	(2.3)	(.5
- Springfield - Chicopee-Holyoke, Mass	.5	81.7	4.3	14.0	46.5	52.4	1.1	(1.1)	(-
- Flint, Mich.	.4	94.3	--	5.7	47.7	51.1	1.2	(1.2)	(-
- Wilmington, Del. - N.J.	.4	74.6	4.6	20.8	46.5	50.8	2.7	(2.6)	(.1
- Wilkes-Barre - Hazelton,Pa	.3	79.5	7.3	13.2	43.4	50.5	6.1	(1.2)	(4.9
- Canton, Ohio	.3	84.3	5.2	10.5	47.3	50.5	2.2	(1.9)	(.3
- Bridgeport, Conn.	.3	91.7	1.8	6.5	49.0	50.5	.5	(.5)	(-
- Worcester, Mass.	.3	75.5	5.1	19.4	48.7	50.2	1.1	(1.1)	(-
- Lancaster, Pa.	.3	86.2	2.3	11.5	41.4	49.6	9.0	(8.6)	(.4
- Reading, Pa.	.3	90.3	3.7	6.0	46.5	49.5	4.0	(3.6)	(.4
- Erie, Pa.	.3	78.1	7.4	14.5	48.1	48.7	3.2	(3.2)	(-
Group 2 - Very low transportation and wholesaling - More tertiary functions.									
Average of the group		68.6	1.8	29.6					
- Dayton, Ohio	.7	76.2	---	23.8	43.6	54.2	2.2	(2.1)	(.1
- Hartford, Conn.	.5	64.2	2.1	33.7	45.2	52.6	2.2	(2.2)	(-
- Utica - Rome, N.Y.	.3	65.5	3.2	31.3	44.9	50.3	4.8	(4.6)	(.2
Group 3 - More transportation and wholesaling									
Average of the group		65.0	10.2	24.8					
- Chicago, Ill.	6.2	81.3	11.6	7.1	33.4	65.8	.8	(.7)	(.1
- Boston, Mass.	2.6	59.5	7.9	32.6	38.2	61.1	.7	(.6)	(.1
- St Louis, Mo. - Ill	2.1	72.3	12.9	14.8	38.5	59.9	1.6	(1.3)	(.3
- Baltimore, Md.	1.7	61.8	9.9	28.3	39.6	59.0	1.4	(1.3)	(.1

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- Paterson-Clifton-Passaic, N.J.	1.2	77.5	11.1	11.4	42.0	57.3	.7	(.6)	(.1)
- Cincinnati, Ohio - Ky.	1.1	67.3	11.2	21.5	42.8	56.3	.9	(.8)	(.1)
- Liousville, Ky - Ind.	.7	60.9	13.3	25.8	44.0	54.6	1.4	(1.3)	(.1)
- Indianapolis, Ind.	.7	60.0	12.1	27.9	45.1	54.2	.7	(.6)	(.1)
- Albany - Schenectady-Troy, N.Y.	.7	54.7	8.4	36.9	44.1	54.0	1.9	(1.8)	(.1)
- Syracuse, N.Y.	.6	67.6	8.5	23.9	43.3	53.3	3.4	(3.2)	(.2)
- Toledo, Ohio	.5	64.9	13.4	21.7	46.7	52.2	1.1	(1.0)	(.1)
- Knoxville, Tenn.	.4	56.5	8.7	34.8	45.5	50.8	3.7	(2.7)	(1.0)
- Grand Rapids, Mich.	.4	65.6	10.4	24.0	46.9	50.8	2.3	(2.1)	(.2)
- Wichita, Kans.	.3	59.4	9.4	31.2	46.5	50.5	3.0	(1.8)	(1.2)
- New Haven, Conn.	.3	57.5	13.6	28.9	49.3	49.8	.9	(.8)	(.1)
- Beaumont-Port Arthur, Texas	.3	56.0	9.6	34.4	46.7	49.8	3.5	(1.7)	(1.8)
- Peoria, Ill.	.3	70.5	9.1	20.4	46.5	49.8	3.7	(3.5)	(.2)
- Chattanooga, Tenn. - Ga.	.3	63.8	7.5	28.7	48.3	49.7	2.0	(1.8)	(.2)
- Johnston, Pa.	.3	70.4	8.3	21.3	38.9	49.7	11.4	(3.5)	(7.9)
- Davenport - Rock Island - Moline, Iowa - Ill.	.3	71.6	7.5	20.9	47.0	49.2	3.8	(3.7)	(.1)
Group 4 - High transportation and wholesaling									
Average of the group		67.6	19.6	12.8					
- Jersey City, N.J.	.6	67.6	19.6	12.8	46.3	53.6	.1	(.1)	(-)
INTERMEDIATE CITIES									
Group 5 - Very low transportation and wholesaling									
Average of the group		50.7	2.6	46.7					

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- San Diego, Calif.	1.0	41.6	1.6	56.8	40.5	56.3	3.2	(3.0)	(.2)
- San Jose, Calif.	.6	57.1	3.4	39.5	42.6	53.8	3.6	(3.5)	(.1)
- Lansing, Mich.	.3	48.4	2.1	49.5	45.0	49.8	5.2	(5.1)	(.1)
- Trenton, J.J.	.3	55.6	3.3	41.1	49.6	49.0	1.4	(1.3)	(.1)
Group 6 - High transportation and wholesaling									
Average of the group		41.4	17.4	41.2					
- New York, N.Y.	10.7	54.4	15.7	29.9	31.0	68.5	.5	(.4)	(.1)
- San Francisco - Oakland, Calif.	2.8	36.5	16.4	47.1	36.8	61.6	1.6	(1.4)	(.2)
- Minneapolis - St. Paul, Minn.	1.5	47.9	18.7	33.4	40.3	58.3	1.4	(1.3)	(.1)
- Houston, Texas	1.2	39.8	23.0	37.2	38.8	57.5	3.7	(1.1)	(2.6)
- Seattle, Wash.	1.1	52.3	15.8	31.9	41.1	56.8	2.1	(2.0)	(.1)
- Dallas, Texas	1.1	39.4	18.2	42.4	39.8	56.5	3.7	(2.5)	(1.2)
- Kansas City, Mo.-Kans.	1.0	45.7	23.4	30.9	42.3	56.3	1.4	(1.2)	(.2)
- Atlanta, Ga.	1.0	37.1	19.7	43.2	42.6	56.3	1.1	(1.0)	(.1)
- Denver, Colo.	.9	29.5	16.4	54.1	41.3	55.8	2.9	(2.0)	(.9)
- Portland, Oreg.-Wash.	.8	37.4	22.4	40.2	40.9	55.3	3.8	(3.7)	(.1)
- Columbus, Ohio	.7	45.8	9.3	44.9	44.7	54.0	1.3	(1.0)	(.3)
- Birmingham, Ala.	.6	49.5	13.5	37.0	42.9	53.7	3.4	(.7)	(2.7)
- Memphis, Tenn.	.6	31.6	20.2	48.2	44.1	53.7	2.2	(2.1)	(.1)
- Fort Worth, Texas	.6	48.1	14.3	37.6	43.8	53.4	2.8	(1.8)	(1.0)
- Tulsa, Okla	.4	36.8	24.7	38.5	40.5	51.7	7.8	(2.1)	(5.7)
- Richmond, Va.	.4	37.6	15.5	46.9	47.6	51.5	.9	(.8)	(.1)
- Nashville, Tenn.	.4	36.4	14.2	49.4	47.3	51.5	1.2	(1.1)	(.1)

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- Harrisburg, Pa.	.3	38.8	13.7	47.5	46.5	50.5	3.0	(2.7)	(.3)
- Tacoma, Wash.	.3	35.8	11.3	52.9	46.6	50.2	3.2	(3.1)	(.1)
- Charlotte, N.C.	.3	36.7	21.6	41.7	49.4	49.2	1.4	(1.4)	(-)
- Des Moines, Iowa	.3	32.4	15.9	51.7	48.6	49.0	2.4	(2.3)	(.1)
- Huntington - Ashland, W.va.-Ky. Ohio	.3	52.1	18.8	29.1	48.0	48.7	3.3	(2.2)	(1.1)
- Charleston, W.Va.	.3	50.2	18.0	31.8	46.5	48.7	4.8	(.6)	(4.2)
Group 7 : Very high transportation and wholesaling									
Average of the group		25.6	28.7	45.7					
- New Orleans, La.	.9	21.4	28.6	50.0	42.1	55.4	2.5	(.7)	(1.8)
- Omaha, Nebr. - Iowa	.5	32.6	27.4	40.0	44.3	52.2	3.5	(3.4)	(.1)
- Duluth - Superior, Minn.-Wisc.	.3	22.7	30.1	47.2	35.5	49.6	14.9	(2.3)	(12.6)
TERTIARY CITIES									
Group 8 - High transportation and wholesaling									
Average of the group		17.8	20.7	61.5					
- Miami, Fla.	.9	10.0	21.9	68.1	41.8	55.8	2.4	(2.3)	(.1)
- Jacksonville, Fla.	.5	14.6	21.6	63.8	46.4	52.2	1.4	(1.3)	(.1)
- Salt Lake City, Utah	.4	25.2	19.9	54.9	42.4	51.3	6.3	(1.4)	(4.9)
- Fresno, Calif.	.4	19.3	20.8	59.9	30.8	50.8	18.4	(17.7)	(.7)
- El Paso, Texas	.3	21.6	19.3	59.1	47.8	49.9	2.3	(2.1)	(.2)
- Shreveport, La.	.3	13.5	20.9	65.6	42.8	49.7	7.5	(3.8)	(3.7)
- Spokane, Wash.	.3	20.5	20.8	58.7	47.0	49.6	3.4	(3.3)	(.1)
Group 9 - Medium in transportation and wholesaling									
Average of the group		17.9	12.1	70.0					

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- San Bernardino- Riverside-Ontario, Calif.	.8	26.2	8.5	65.3	36.2	55.2	8.6	(8.0)	(.6)
- Tampa- St.Petersburg, Fla.	.8	21.5	12.6	65.9	41.2	54.8	4.0	(3.6)	(.4)
- San Antonio, Texas	.7	8.5	11.2	80.3	43.4	54.0	2.6	(2.0)	(.6)
- Phoenix, Ariz.	.7	25.0	10.7	64.3	37.7	54.0	8.3	(8.1)	(.2)
- Norfolk- Portsmouth, Va.	.6	20.0	16.7	63.3	45.0	53.4	1.6	(1.6)	(-)
- Oklahoma City, Okla.	.5	11.2	14.5	74.3	43.3	52.4	4.3	(2.1)	(2.2)
- Sacramento, Calif.	.5	22.1	9.7	68.2	44.3	52.4	3.3	(3.1)	(.2)
- Honolulu, Hawai	.5	14.7	14.9	70.4	44.3	52.4	3.3	(3.2)	(.1)
- Orlando, Fla.	.3	24.2	10.8	65.0	41.7	50.1	8.2	(8.1)	(.1)
- Mobile, Ala.	.3	23.3	14.6	62.1	47.6	49.9	2.5	(2.2)	(.3)
- Bakersfield, Calif.	.3	11.7	13.2	75.1	29.5	49.8	20.7	(15.2)	(5.5)
- Tucson, Ariz.	.3	13.6	9.5	76.9	44.4	49.0	6.6	(2.6)	(4.0)
- Albuquerque, N.Mex.	.3	6.6	12.8	80.6	49.4	48.9	1.7	(1.4)	(.3)
- Columbia, S.C.	.3	21.9	10.2	67.9	47.9	48.8	3.3	(3.1)	(.2)
Group 10 - Highly specialized in tertiary functions									
Average of the group		4.6	5.1	90.4					
- Washington, D.C.- Md.-Va.	2.0	--	4.1	95.9	39.8	59.3	.9	(.8)	(.1)
- Fort Lauderdale-Hollywood, Fla.	.3	9.1	6.1	84.8	44.6	50.4	5.0	(4.8)	(.2)

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